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Operation TEAPOT

NEVADA TEST SITE

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Project 32.2

EFFECTS OF NUCLEAR EXPLOSIONS ON CANNED FOODS

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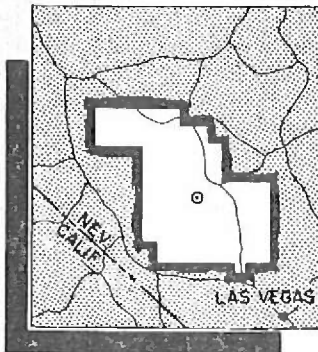
CIVIL EFFECTS TEST GROUP

NOTICE

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Report to the Test Director

EFFECTS OF NUCLEAR EXPLOSIONS
ON CANNED FOODS

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ABSTRACT

To test the effect of nuclear explosions upon heat-sterilized foods canned in both tin and glass containers, 60 different commercial products covering the categories of vegetables, fruits, juices, fish and shellfish, meats and poultry, specialties, soups, baby foods, and milk were exposed to a shot having about one and one-half times the 20-kt yield considered as nominal. Exposures covered a wide range of civilian handling conditions in homes, commercial storage, retail outlets, and emergency shelters to determine the suitability for use of canned foods either immediately or after some period of storage.

Results of radiological, chemical, bacteriological, and organoleptic tests revealed that canned foods in unbroken tin or glass containers, subjected to an atomic blast, are suitable for immediate use when located in shelters or other structures effective in protecting personnel against lethal radiation or blast effects. Their induced radioactivity is not at a dangerous level, and any container failure is readily discernible. Canned foods that might be recoverable from critically exposed areas within the zone of complete destruction could be pressed into emergency service after three or four days. To minimize mechanical crushing and perforation damage, basement storage of canned foods is preferable to kitchen storage, and the storage area should be out of direct line with windows or doors.

Under extreme conditions of exposure to blast overpressures of 45 psi at $\frac{1}{4}$ mile from Ground Zero (comparable to complete destruction of structures), there was some obvious container destruction, and radioactivity was induced in the foods and containers by the high radiation level. If unopened containers show considerable activity when monitored after an explosion, they should not be discarded. Container radioactivity has no bearing on the suitability of the food for use. The container should be brushed, wiped, or washed to remove fallout material and opened so that the contents can be monitored. Very active containers, in many instances, will contain food that is entirely safe. Visual indications of extreme exposure are sharp crushing deformations of can bodies or coloration of glass jars.

No significant losses in nutrient values occurred, and no harmful effects were observed in monkeys, rats, and dogs fed on the critically exposed foods.

ACKNOWLEDGMENTS

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CHAPTER 1

OBJECTIVES

The objective of this project was to test the effects of nuclear explosions upon heat-sterilized foods canned in both tin and glass containers. The conditions of exposure were planned to simulate the range encountered in normal handling of processed foods in homes, commercial storage, retail outlets, and emergency shelters. The effects of exaggerated conditions of high blast overpressures and intense neutron and gamma radiation were studied at the shortest possible distances without actual physical destruction of the test materials. The aims were to determine the suitability for use of such foods, either immediately or after some period of storage, and to develop a public understanding of the results with respect to any preferable conditions of storage.

To accomplish these objectives, the project was divided into five tests, on a functional design basis, as follows:

Test 1: General test on container damage and physical and organoleptic effects on products.

Test 2: Special incubation test on influence of internal vacuum and container size upon container damage and spoilage.

Test 3: Special test on removal of fall-out contamination.

Test 4: Special test on retention of essential nutritive factors.

Test 5: Special feeding tests to demonstrate safety.

CHAPTER 2

BACKGROUND

2.1 TYPES AND AMOUNTS OF FOODS EXPOSED

All samples were commercially packed in hermetically sealed heat-processed tin cans or glass jars and were contributed by the members of the sponsoring organizations as a public service (Table 2.1). They represented the complete range of container size. The products, chosen on the basis of production volume and physical characteristics, covered the categories of vegetables, fruits, juices, fish and shellfish, meats and poultry, specialties, soups, baby foods, and milk. In Test 1 there were 47 foods packed in 21 can sizes and 23 foods packed in 8 jar sizes. The products and container sizes used in each test are listed in Table 2.2. A total of 908 cases and 3802 uncased cans and jars was exposed.

The nutrient medium used in Test 2 consisted of 10 per cent dried peas and 0.75 per cent cane-sugar solution in water. The cans were sealed under approximately 5 in., 12 to 14 in., and 20 + in. of vacuum. Jars were sealed under 20 + in. of vacuum.

The mixed-vegetable pack for monkey feeding, a part of Test 5, consisted of equal quantities of rutabagas, sweet potatoes, white potatoes, and carrots. The vegetables were steam peeled, hand trimmed, cut into $\frac{1}{2}$- to $\frac{3}{4}$-in. sections, sealed under vacuum without added liquid, and processed for 60 min at 240°F.

Samples for nutritive analysis were selected from acid and low-acid products on the basis of their normal high- or low-level content of certain essential nutritive factors, as follows:

Product	Nature of product	Description
Apricots	Acid	High carotene
Peaches	Acid	Low ascorbic acid
Orange juice	Acid	Low carotene and high ascorbic acid
Tomato juice	Acid	High ascorbic acid
Peas	Low acid	Moderate niacin
Chopped spinach	Low acid	High carotene and high ascorbic acid
Luncheon meat	Low acid	Moderate thiamine
Tuna	Low acid	Moderate thiamine and high niacin
Evaporated milk	Low acid	High riboflavin

Table 2.1 — CONTRIBUTORS TO THE CANNED-FOOD NUCLEAR TEST PROGRAM

Alton Canning Co., New York
American Home Foods, Inc., Pennsylvania
American Stores Co., Pennsylvania
Apple Growers Assn., Oregon
Armour & Co., Illinois
Athens Canning Co., Texas

Baldwin Packers, Ltd., Maui, T. H.
R. K. Barter Canneries, Inc., Maine
Beech Nut Packing Co., New York
Big Horn Canning Co., Wyoming
Big Stone Canning Co., Minnesota
Bison Canning Co., Inc., New York
Bixby Canning Co., Inc., Oklahoma
Blue Lake Packers, Inc., Oregon
F. E. Booth Co., California
Bordo Products Co., Illinois
Bricelyn Cooperative Canning Association, Minnesota
Burnham & Morrill Co., Maine
Bush Bros. & Co., Tennessee
Butterfield Canning Co., Indiana

California Packing Corp., California
Calumet-Dutch Packing Co., Wisconsin
Campbell Soup Co., New Jersey
Canned Foods, Inc., Wisconsin
H. P. Cannon & Son, Inc., Delaware
Carolina Recipes, Inc., South Carolina
Clarksville Canning Co., Iowa
Consolidated Food Processors, Inc., Illinois
Country Gardens, Inc., Wisconsin
Crosse & Blackwell Co., Maryland
Curtice Brothers Co., New York

Domino Canning Co., Florida
Draper Canning Co., Delaware
Draper Foods, Inc., Delaware
John H. Dulany & Son, Maryland

Eaton Canning Co., Indiana
The Elgin Canning Co., Iowa
Empire State Pickling Co., New York
The Esmeralda Canning Co., Ohio
Eugene Fruit Growers Assn., Oregon

Fairmont Canning Co., Minnesota
Fall River Canning Co., Wisconsin
Falls Canning Co., Inc., Wisconsin
Farm Fresh Packing Corp., New Jersey
Fernando Canning Co., California
Filice & Perrelli Canning Co., Inc., California
Fort Lupton Canning Co., Colorado
The Frank Pure Food Co., Wisconsin
Fremont Kraut Co., Ohio
S. E. W. Friel, Maryland
Friend Bros., Inc., Massachusetts
Fruit Belt Preserving Co., New York
Fruit Growers Co-operative, Wisconsin
J. W. Furman Cannery, Pennsylvania

Gerber Products Co., Michigan
The Greencastle Packing Co., Pennsylvania
Growers & Packers Cooperative Canning Co., Inc., New York
Gypsum Canning Co., Ohio

Hawaiian Pineapple Co., Ltd., California
Haxton Foods, Inc., New York
H. J. Heinz Co., Pennsylvania
Hirzel Canning Co., Ohio
Holmes Packing Corporation, Maine
J. William Horsey Corp., Florida
G. W. Hume Co., California
Hunt Foods, Inc., California

Idaho Canning Co., Idaho
Illinois Canning Co., Illinois

R. W. Jones Canning Co., Inc., Indiana

Kauai Pineapple Co., Ltd., Kauai, T. H.
Kayler-Dahl Fish Co., Washington
Keystone Cooperative Grape Assn., Pennsylvania
King Pharr Canning Operations, Inc., Mississippi
kuner-Empson Co., Colorado

Lake County Cannery, Inc., California
Lake Odessa Canning Co., Michigan
Lakeside Packing Co., Wisconsin
Larsen Co., Wisconsin
Lawrence Packing Co., Michigan
Tom Lazio Fish Co., Inc., California
Libby, McNeill & Libby, Illinois
The Lyndonville Canning Co., Inc., New York

H. J. McGrath Co., Maryland
McKeon Canning Co., Inc., California
Maine Sardine Packers Association, Massachusetts
Mammoth Springs Canning Co., Wisconsin
Marshall Canning Co., Iowa
Maui Pineapple Co., Ltd., Maui, T. H.
Mavar Shrimp & Oyster Co., Ltd., Mississippi
Oscar Mayer & Co., Wisconsin
Meeter Bros. & Co., Wisconsin
Michigan Mushroom Co., Michigan
Morgan Packing Co., Indiana
John Morrell & Co., Iowa
Morton Canning Co., Inc., New York
E. B. Muller & Co., Michigan

Naas Corporation, Indiana
Herbert A. Nieman & Co., Wisconsin
North Lubec Mfg. & Canning Co., Maine
Northwest Packing Co., Oregon

Old Virginia Packing Co., Inc., Virginia
Olympia Canning Co., Washington
Owatonna Canning Co., Minnesota

Pacific American Fisheries, Inc., Washington
Pan Pacific Fisheries, Inc., California
R. J. Peacock Canning Co., Maine

Port Clyde Packing Co., Inc., New York
Pulaski Canning Co., Wisconsin

Quaker Maid Co., New York

Reinbeck Canning Co., Iowa
Richmond-Chase Company, California
P. J. Ritter Co., New Jersey
Robinson Canning Co., Inc., Louisiana
Rogers Canning Co., Oregon

S & W Fine Foods, Inc., California
San Juan Fishing & Packing Co., Washington
Sauk City Canning Co., Wisconsin
Schukl & Co., Inc., California
Seabrook Farms Co., New Jersey
Shiocton Kraut Co., Wisconsin
The Silver Canning Co., Maryland
Silver Creek Preserving Corporation, New York
J. R. Simplot Co., Idaho
Skinner & Eddy Corporation, Inc., Washington
Smith Frozen Foods of Idaho, Inc., Idaho
Southern Shell Fish Co., Louisiana
Stahl-Meyer, Inc., New York
Star-Kist Foods, Inc., California
Steele Canning Co., Arkansas
A. L. Stewart & Son, Maine
Stokely—Van Camp, Inc., Indiana

Sunshine Packing Corporation of Pennsylvania, Pennsylvania
G. S. Suppiger Co., Illinois
C. A. Swanson & Sons, Nebraska

Thomas & Company, Maryland.
Thornton Canning Co., California
Treesweet Products Co., California
Tripoli Canning Co., Inc., Iowa
Tuhey Canning Co., Indiana
Turlock Cooperative Growers, California

Uddo & Taormina Co., California
United Packers, Inc., Illinois
Utah Canning Co., Utah

Van Camp Sea Food Company, Inc., California
Ver-Nal Canning Co., California

Walnut Creek Canning Co., California
R. S. Watson & Son, New Jersey
Westfield Planters Co-operative Fruit Product Inc., New York
Westgate-California Tuna Packing Co., Califor
Whiz Fish Products Co., Washington
Wilson & Co., Inc., Illinois
D. E. Winebrenner Co., Pennsylvania
Winorr Canning Co., Ohio
Wood Canning Co., California

Organizations

American Meat Institute
Can Manufacturers Institute
Evaporated Milk Association

Glass Container Manufacturers Institute, Inc.
National Canners Association
National Meat Canners Association

Table 2.2—HEAT-PROCESSED PRODUCTS AND CONTAINER SIZES
EXPOSED AT OPEN SHOT

| Product | Container size | |
	Tin	Glass

Test 1

Vegetables
Corn (whole kernel)	303 × 406	
Tomatoes	307 × 409	
Peas	303 × 406	
Green beans	303 × 406	16 oz
Beets	303 × 406	16 oz
Sauerkraut	401 × 411	
Sweet potatoes	404 × 307	
White potatoes		16 oz
Carrots		16 oz

Fruits
Peaches	401 × 411	
Pineapple	401 × 411	
Pears	401 × 411	
Fruits for salad		28 oz
Applesauce	303 × 406	
Grapefruit	303 × 406	
Blueberries	300 × 407	
Blackberries	303 × 406	
Purple plums	401 × 411	28 oz
R.S.P. cherries	307 × 409 and 603 × 700	

Juices
Tomato	404 × 700	
Orange	404 × 700	
Pineapple	404 × 700	
Apple		32-oz bottle
Grape		12-oz bottle

Fish and shellfish
Salmon	301 × 411	
Tuna	307 × 113	
Sardines in oil	¼ drawn, scored	
Sardines in oil	¼ drawn, unscored	
Sardines in tomato sauce	1 lb (oval)	
Shrimp	211 × 300	6-oz tumbler

Meats and poultry
Luncheon meat	12 oz (rectangular)	
Hamburgers	300 × 308	
Frankfurters	300 × 407	8 oz
Chicken (boned)	303 × 108	

Specialties
Pork and beans	300 × 407	
Beef stew	302 × 402	
Spaghetti	300 × 407	
Corned beef hash	302 × 402	
Catsup		14-oz bottle
Chicken ravioli		14 oz

	Container size	
Product	Tin	Glass
Soups		
Tomato	211 × 400	
Vegetable-beef	211 × 400	
Mushroom	211 × 400	
Mushroom (ready to serve)	211 × 414	
Consommé	211 × 400	
Baby foods		
Strained spinach	202 × 214	5 oz
Strained carrots	202 × 214	5 oz
Strained apricots and apples	202 × 214	5 oz
Strained bananas	202 × 214	5 oz
Strained chicken soup	202 × 214	5 oz
Strained lamb and vegetables	202 × 214	5 oz
Strained liver and vegetables	202 × 214	5 oz
Strained vanilla custard	202 × 214	5 oz
Strained beef	202 × 202	3½ oz
Evaporated milk	14½ oz (snap end)	

<center>Test 2</center>

Product	Tin	Glass
Strained chicken soup	202 × 214	5 oz
Junior chicken soup	211 × 210	8 oz
Tomatoes	303 × 406 and 401 × 411	
Peas	303 × 406	
Cream-style corn	303 × 406 and 603 × 700	
Whole-kernel corn (vacuum packed)	307 × 306	
Sweet potatoes	404 × 307	
Pears	401 × 411	
Pumpkin	401 × 411	
Tomato juice	404 × 700	
Spinach	603 × 700	
Applesauce	603 × 700	
Nutrient medium	202 × 214*	5 oz†
Nutrient medium		8 oz†
Nutrient medium	303 × 406*	16 oz†
Nutrient medium	307 × 409*	
Nutrient medium	401 × 411*	28 oz†
Nutrient medium	404 × 700*	
Nutrient medium	603 × 700 (beaded)*	
Nutrient medium	603 × 700 (un-beaded)*	

<center>Test 3</center>

Product	Tin	Glass
Any	202 × 214	5 oz
Any	307 × 409	16 oz
Any	603 × 700	28 oz

Table 2.2—(Continued)

| | Container size | |
Product	Tin	Glass
Test 4		
Apricots	401 × 411	
Peaches	401 × 411	
Orange juice	307 × 409	
Tomato juice	307 × 409	
Peas	303 × 406	
Chopped spinach	303 × 406	
Luncheon meat	12 oz (rectangular)	
Tuna	307 × 113	
Evaporated milk	$14\frac{1}{2}$ oz (snap end)	
Test 5		
Beef stew	302 × 402	
Strained liver and vegetables		5 oz
Evaporated milk	$14\frac{1}{2}$ oz (snap end)	
Mixed vegetables‡	303 × 406	16 oz

* High, medium, and low vacuums.

† Three types of closures.

‡ Special pack.

All samples were assembled in a government warehouse at Wilmington, Calif., where they were tested for proper vacuum, individually coded, and cased (Figs. 2.1, 2.2, and 2.3). The same products from several packers were composited in equal numbers for each exposure condition in order to cover any normal packing variations. All cases were identified by color and symbol codes showing intended exposure condition and purpose. An adequate number of unexposed duplicate products were held as controls for all tests. Samples were transported to the Nevada Test Site (NTS) at Mercury, Nev., in a trailer which was used also for storage prior to actual placement of the samples (Fig. 2.4).

2.2 BASIS FOR EXPOSURE CONDITIONS IN THE OPEN SHOT

During an earlier shot of Operation Teapot with an approximately nominal yield, canned foods in tin and glass containers were exposed under several conditions at various distances from Ground Zero. The results indicated that foods exposed by burying with a shallow earth cover at about $\frac{1}{4}$ mile from a nominal device could be recovered following the blast and would receive a maximum radiation dose. Unprotected samples exposed at about $\frac{7}{10}$ mile or more suffered little physical damage and no significant levels of induced radioactivity (Figs. 2.5 and 2.6). These results were used in selecting exposure conditions and distances for the open shot.

2.3 METHODS OF EXPOSURE

2.3.1 General

Table 2.3 lists the exposure conditions and the number of samples at each location. Separate listings for the same distance and condition refer to extra samples for specific test purposes. Figure 2.7 shows canned-food locations along the Federal Civil Defense Adminis-
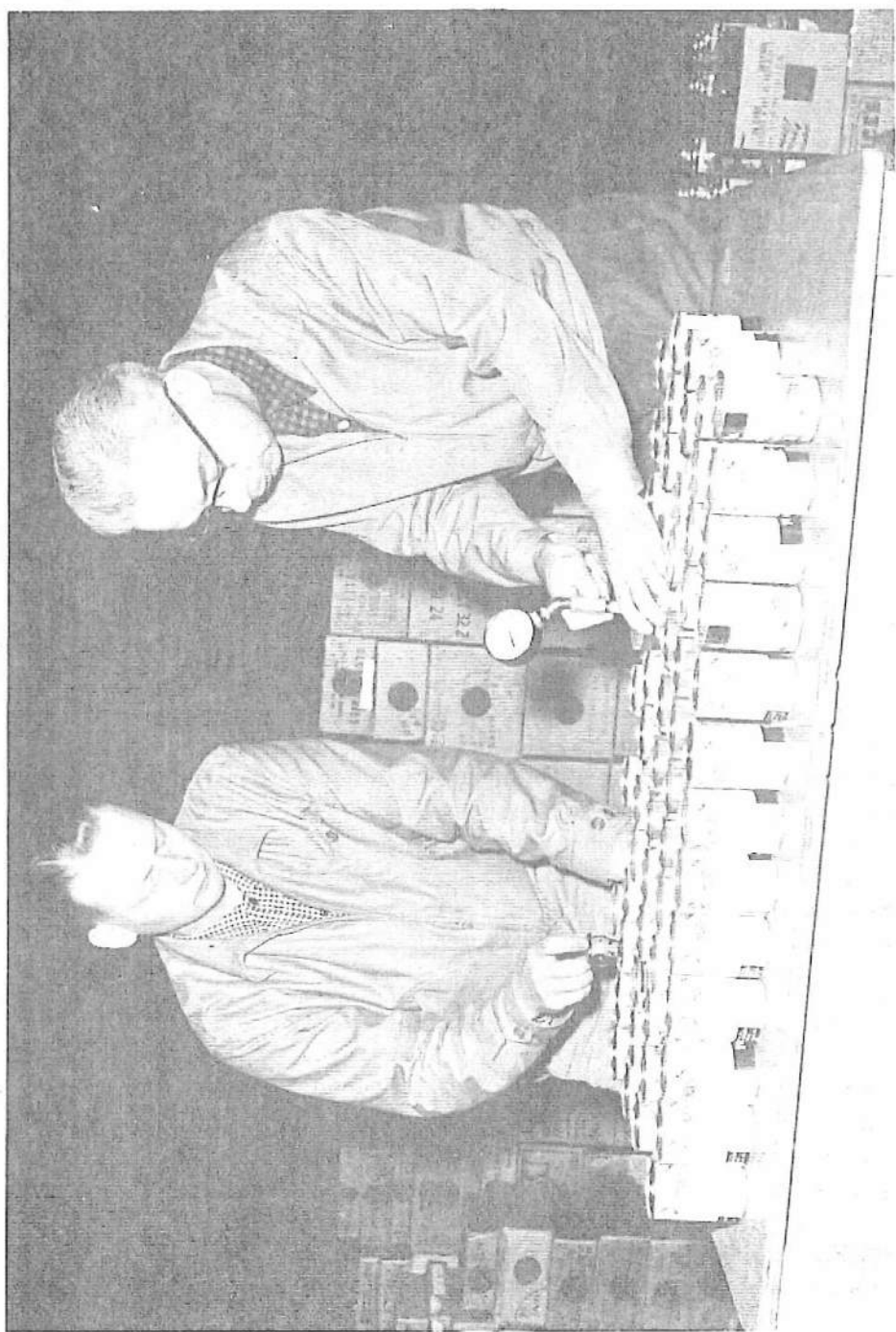
Fig. 2.1 — Flip-vacuum testing and coding of tin containers.
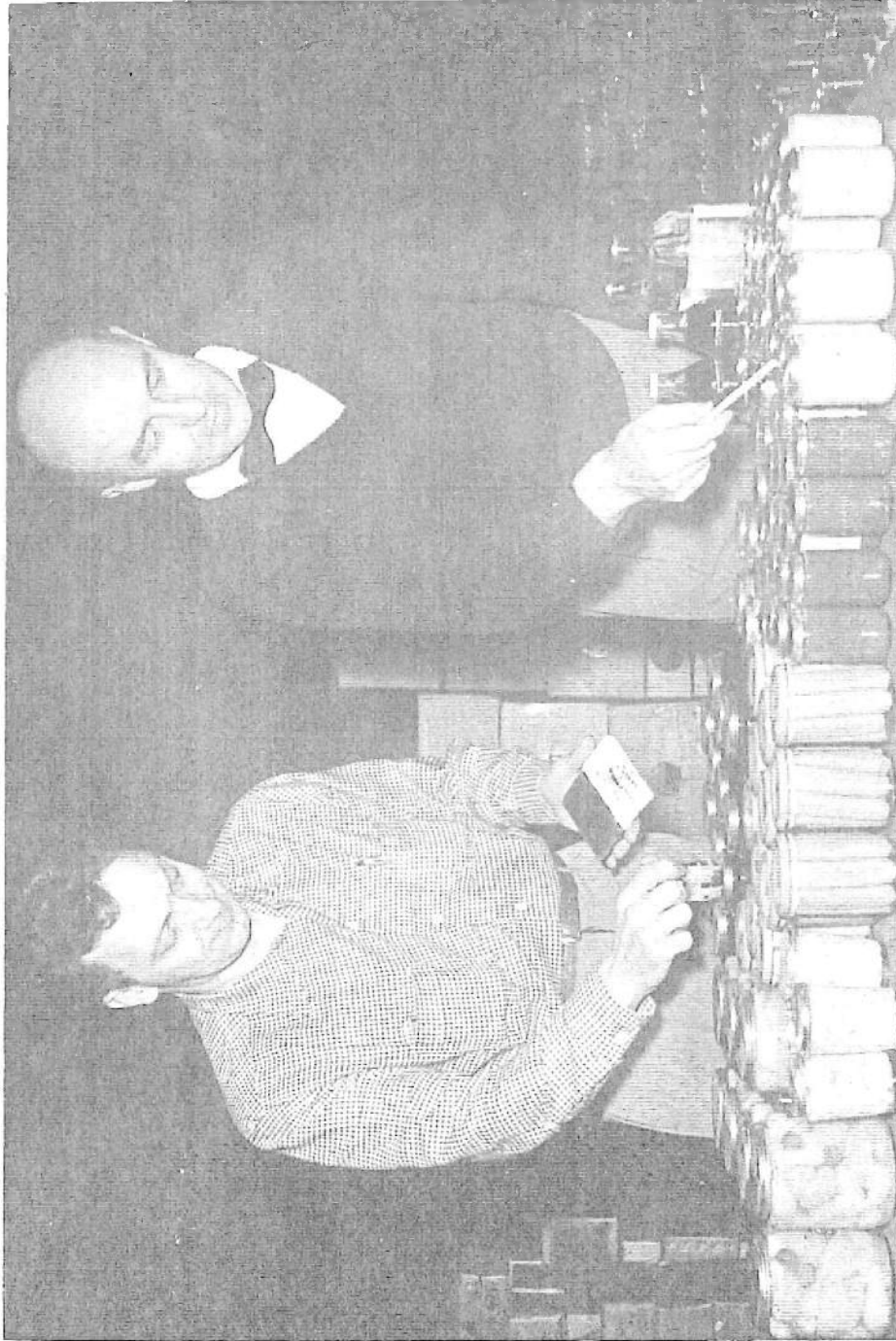
Fig. 2.2—Tap testing for vacuum and coding of glass containers.
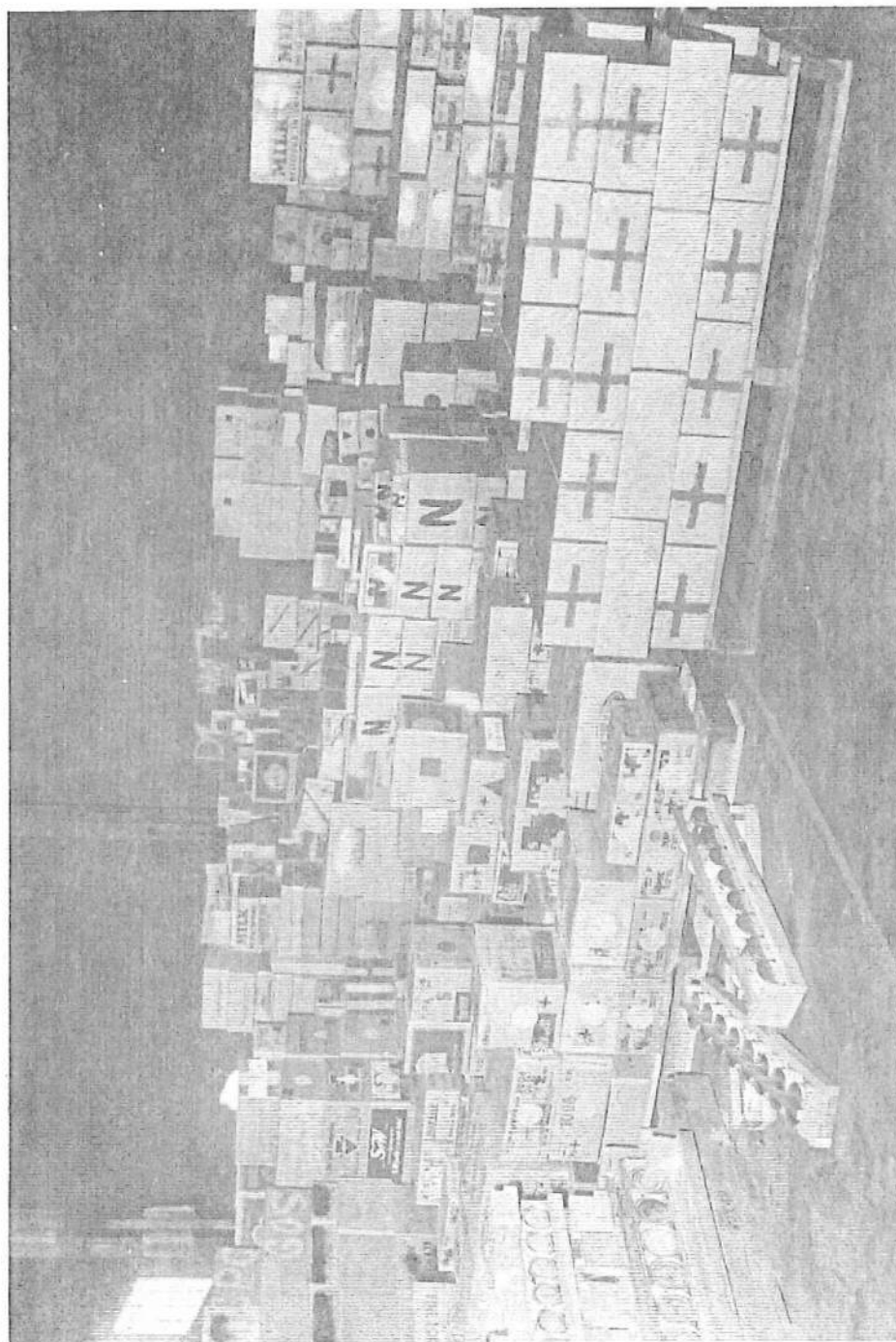
Fig. 2.3 —Coded cased samples ready for trailer transport to the test site.
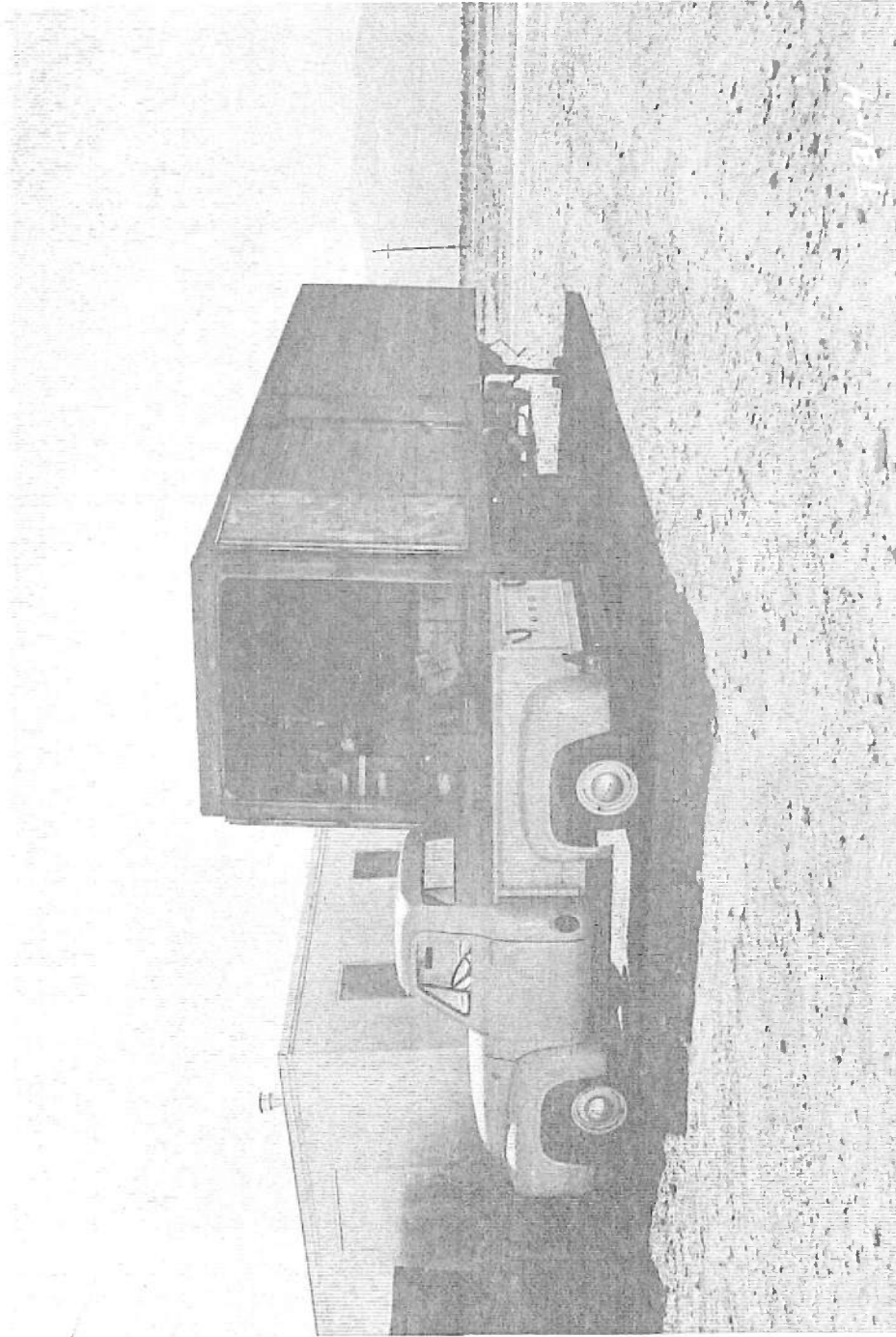
Fig. 2.4 — Transfer of samples at the test site.

Fig. 2.5 — Samples on the ground surface at $7/10$ mile from Ground Zero (to the left) prior to the approximately nominal shot.

Fig. 2.6—Scattered samples at $^7/_{10}$ mile from Ground Zero (to the right) after the approximately nominal shot.

Table 2.3 — EXPOSURE CONDITIONS AND NUMBER OF SAMPLES

Exposure condition	Distance from Ground Zero Feet	Miles (approx.)	Number of units Tin	Glass
Underground group personnel shelter	1,050	$\frac{1}{5}$	12 cans	4 jars
Buried with 2 to 3 in. of earth cover	1,270	$\frac{1}{4}$	147 cases	155 cases
Buried with 2 to 3 in. of earth cover	1,270	$\frac{1}{4}$	28 cases	11 cases
Buried with 2 to 3 in. of earth cover	1,270	$\frac{1}{4}$	35 cases	10 cases
Buried in special racks with 2 to 3 in. of earth cover	1,270	$\frac{1}{4}$	27 racks	
Precast reinforced concrete utility type shelter, cases on shelves and floor	2,250	$\frac{2}{5}$	26 cases	10 cases
Precast reinforced concrete utility type shelter, cases on shelves and floor	2,250	$\frac{2}{5}$	35 cases	10 cases
Masonry block utility type shelter, cases stacked against walls	3,750	$\frac{7}{10}$	24 cases	9 cases
Masonry block utility type shelter, cases stacked against walls	3,750	$\frac{7}{10}$	16 cases	10 cases
One-story precast concrete house, uncased on kitchen shelves	4,700	$\frac{9}{10}$	282 cans	114 jars
Pallet on ground surface	4,700	$\frac{9}{10}$	40 cases	
Two-story white frame house, uncased on kitchen shelves	5,500	1	279 cans	129 jars
Two-story white frame house, uncased on basement shelves, rear wall	5,500	1	270 cans	170 jars
Two-story white frame house, cases on basement shelves, rear wall	5,500	1	35 cases	10 cases
Cases on ground surface	5,500	1	26 cases	11 cases
Cases on ground surface	5,500	1	36 cases	11 cases
Cases on ground surface	5,500	1	18 cases	
Industrial building, uncased on shelves, rear wall	6,800	$1\frac{3}{10}$	500 cans	156 jars
Industrial building, cases stacked against rear wall	6,800	$1\frac{3}{10}$	21 cases	10 cases
Two-story white frame house, uncased on kitchen shelves	7,800	$1\frac{1}{2}$	288 cans	126 jars
Two-story white frame house, uncased on basement shelves, front wall	7,800	$1\frac{1}{2}$	282 cans	114 jars
Two-story white frame house, cases stacked along outer wall of basement concrete shelter	7,800	$1\frac{1}{2}$	16 cases	4 cases
Cases on ground surface	7,800	$1\frac{1}{2}$	25 cases	10 cases
Cases on ground surface	7,800	$1\frac{1}{2}$	16 cases	4 cases
Cases on ground surface	7,800	$1\frac{1}{2}$	18 cases	
One-story precast concrete house, uncased on kitchen shelves	10,500	2	282 cans	132 jars
Industrial building, uncased on shelves, rear wall	15,000	$2\frac{4}{5}$	494 cans	168 jars
Industrial building, cases stacked against rear wall	15,000	$2\frac{4}{5}$	16 cases	4 cases

OPERATION CUE
F.C.D.A. MAIN TEST LINE

10,500

7,800
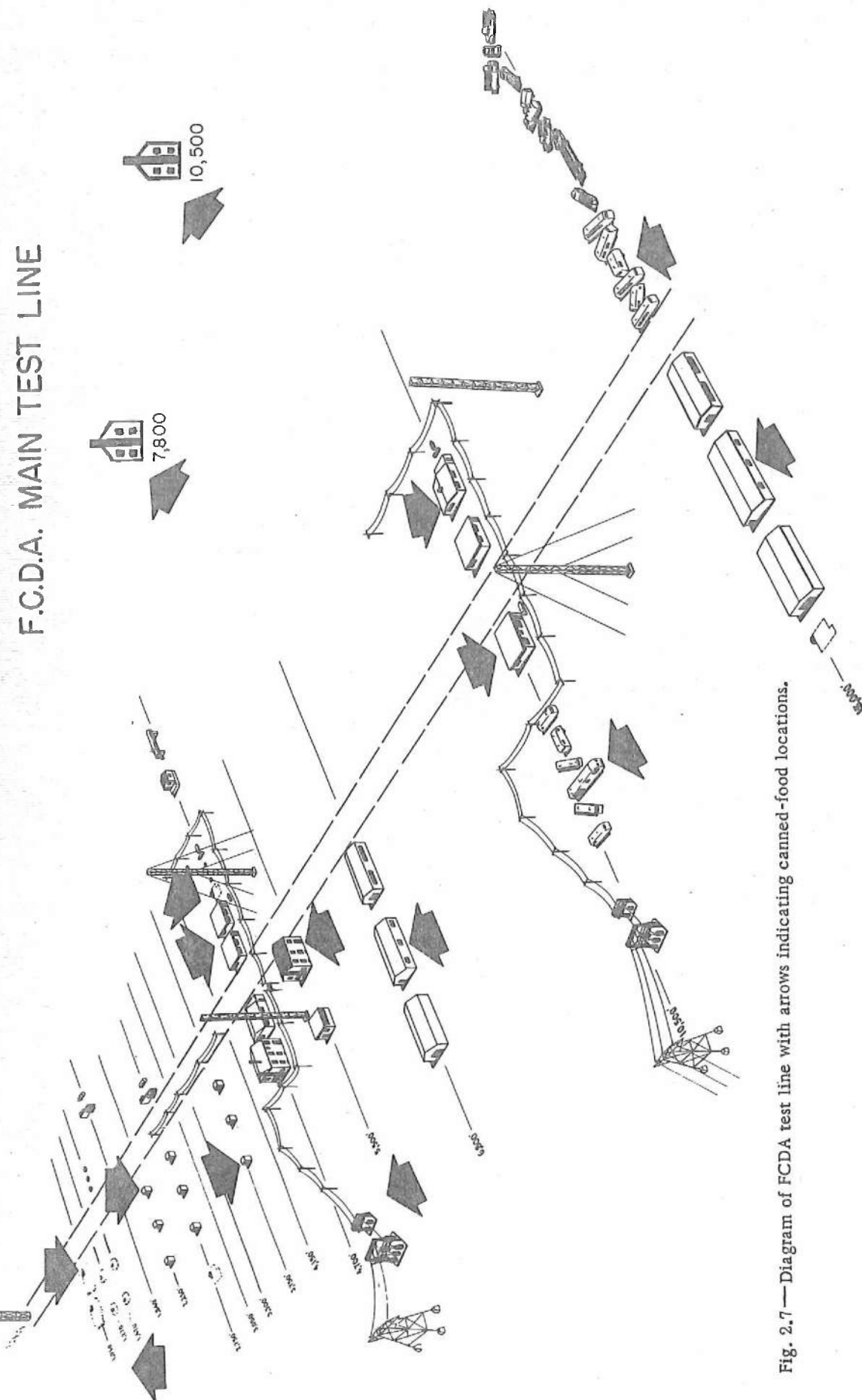
Fig. 2.7—Diagram of FCDA test line with arrows indicating canned-food locations.

tration (FCDA) test line. All general test samples at 1270 ft from Ground Zero were in single-tier cases to avoid self-shielding from radiation. At this distance the cases were placed in shallow trenches; they were covered with planks to facilitate recovery and with 2 to 3 in. of loose soil to prevent burning (Fig. 2.8). Postshot recovery was accomplished readily by removing the planks and lifting the cases from the trenches (Fig. 2.9).

2.3.2 Test 2 (Incubation)

All samples for Test 2 were sealed in cases deliberately inoculated with a mixture of organisms so as to enhance spoilage potentialities. The inoculum, consisting of a talcum suspension of dried yeasts, lactobacilli, and butyric anaerobic spores, was dusted into each sealed case to give a concentration of at least one million organisms of each type.

2.3.3 Test 3 (Fall-out)

Open cases of small, medium, and large tin and glass containers were exposed at 2 and 15 miles from Ground Zero in an attempt to obtain fall-out.

2.3.4 Test 4 (Nutritive)

Samples for subsequent nutritive analysis were assembled in special 8-can wooden racks to afford equal exposure to radiation flux at 1270 ft from Ground Zero and were covered with 2 in. of soil. Samples at 5500 and 7800 ft from Ground Zero were packaged as single-tier 12-can cases and were exposed on the ground surface (Fig. 2.10).

2.3.5 Test 5 (Feeding)

All feeding test samples were buried at 1270 ft from Ground Zero with approximately 2 in. of earth cover. Wooden divider strips were used between cases of vacuum-packed tin products and glass products to protect against blast damage (see Fig. 2.8), and the cases were then covered with a $\frac{3}{4}$-in. plank and 2 in. of soil.

2.3.6 Pallet Load

Figure 2.11 shows a pallet load of cased canned foods placed for exposure at 4700 ft from Ground Zero with no protection.
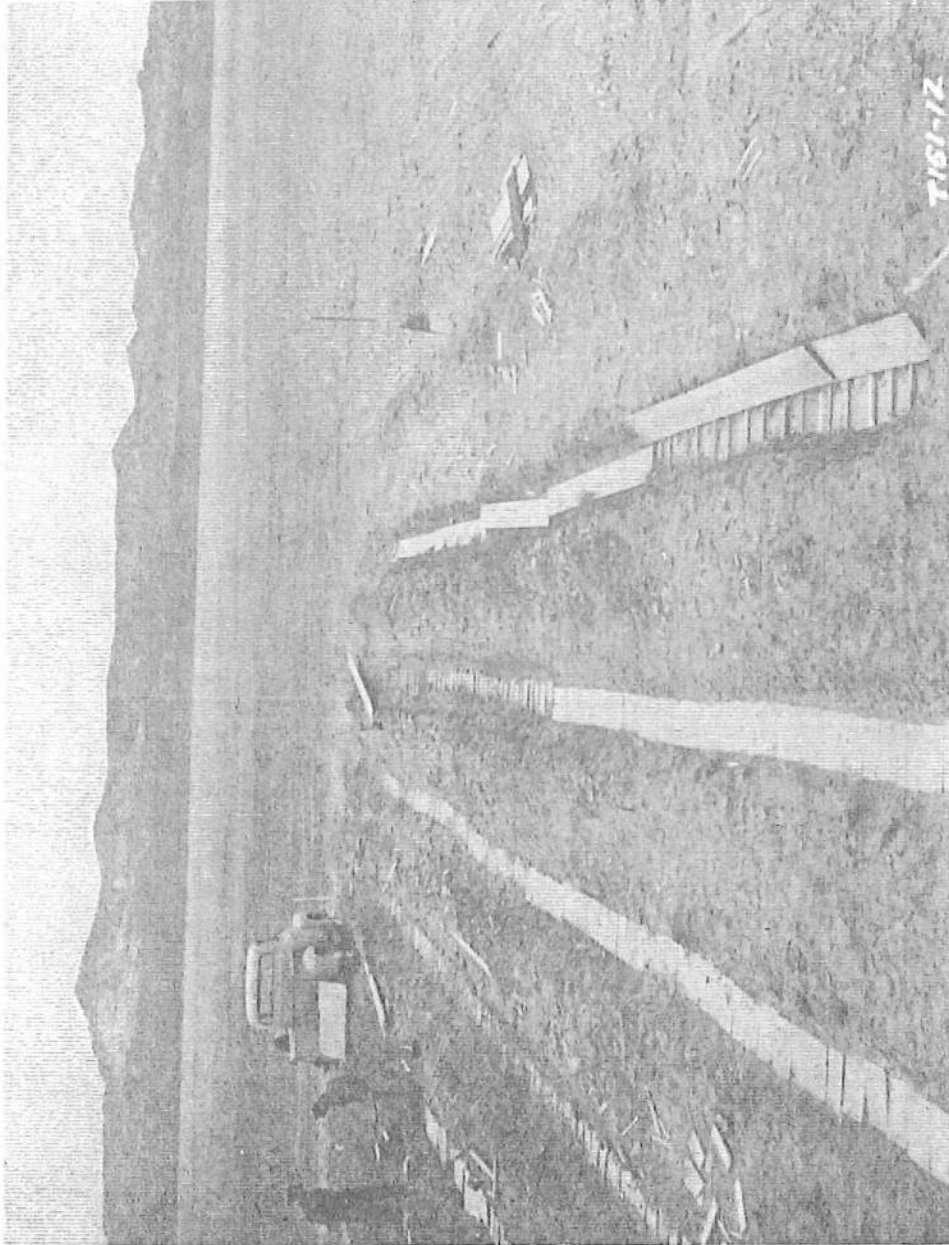
Fig. 2.8 —Samples being placed in trenches at 1270 ft from Ground Zero.
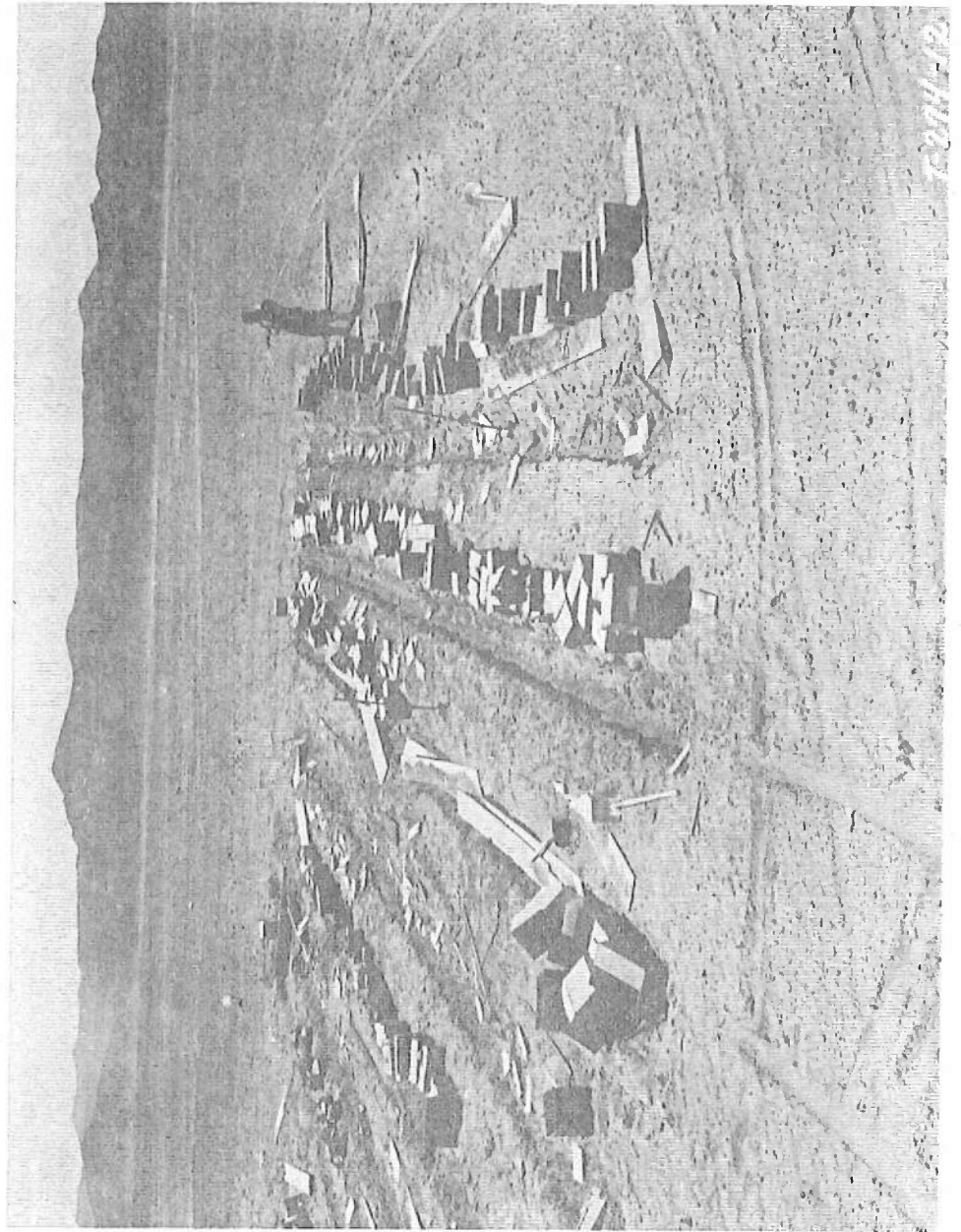
Fig. 2.9 — Cases being recovered at 1270 ft from Ground Zero after the blast. Condition is
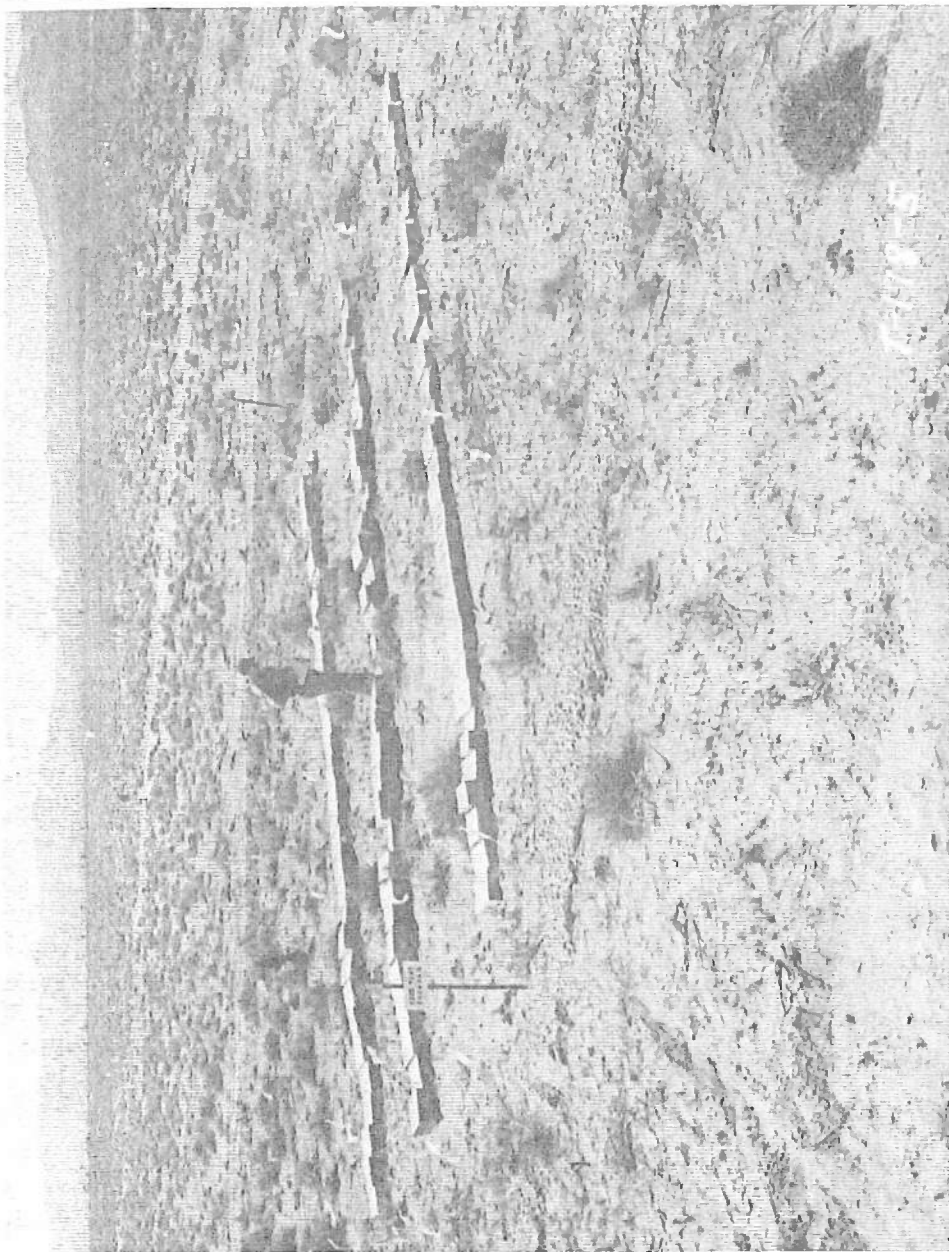
Fig. 2.10 — Cased samples on the ground surface at 5500 ft from Ground Zero before the shot.
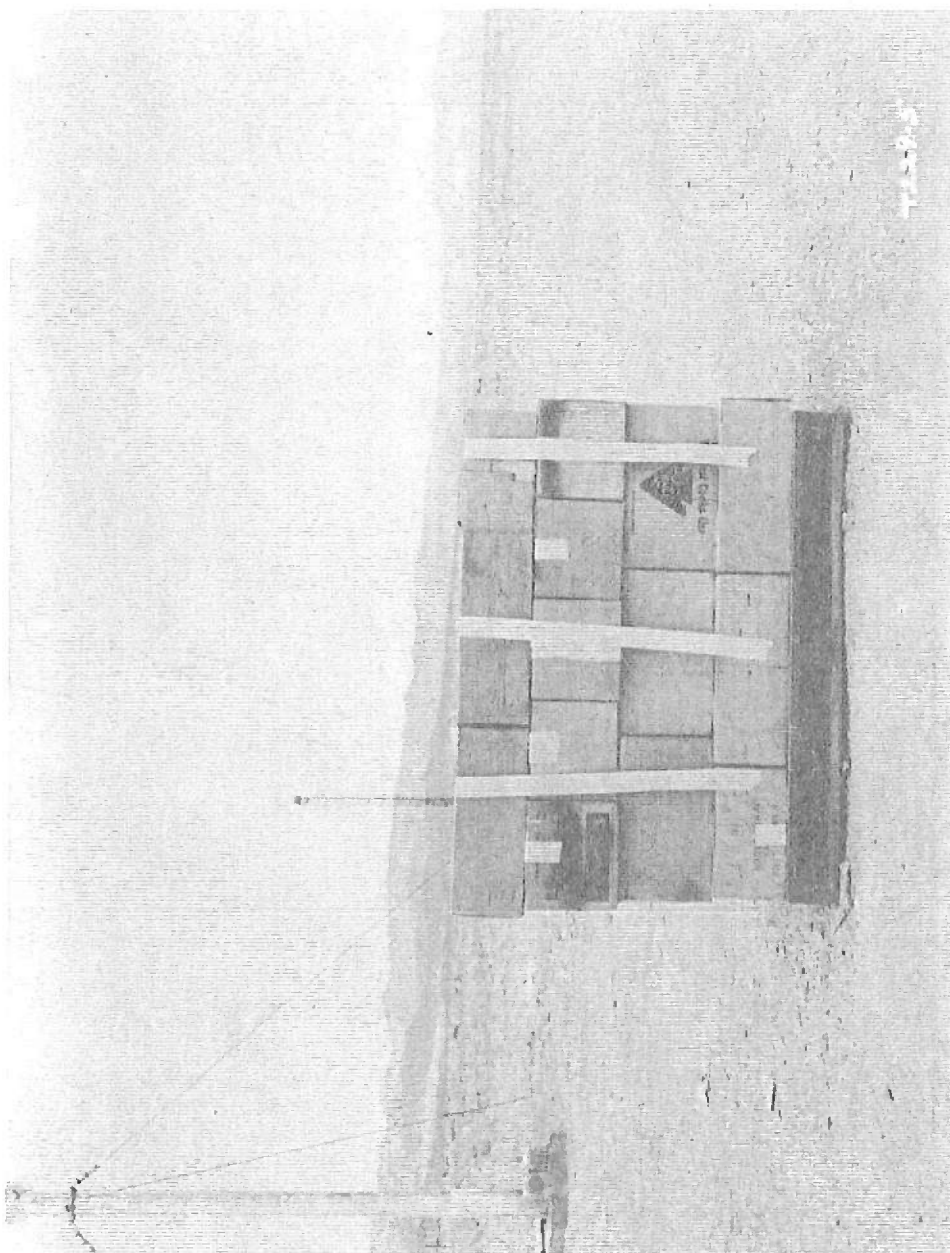
CHAPTER 3

INSTRUMENTATION

3.1 GENERAL

A variety of neutron and/or gamma dosimeters was used to measure the radiation flux at each location. Placements were such as to reveal shielding effects afforded by individual containers or cases of containers, as well as the general radiation dose.

3.2 SPECIFIC

Preshot testing for normal vacuum was conducted with mechanical flip-vacuum instruments for tin containers and by tap test on glass containers (Figs. 2.1 and 2.2). Postshot monitoring for induced radioactivity was conducted in a preliminary way with an Anton 203 precision radioactivity comparator (Anton Electronic Laboratories, Inc., Brooklyn 27, N. Y.), serial No. 101, equipped with Anton 1007, No. 237 Geiger-Mueller (G-M) tube as an external probe. This instrument was standardized against Food and Drug Administration (FDA) No. 8 uranyl acetate standard, which had an activity of about 15.5 mr/hr, embedded in a thermosetting plastic.

Detailed monitoring at the NTS was conducted by scaling uniform metal disks or weighed product samples with scintillation scaler model LS64SS (El-Tronics, Inc., Philadelphia, Pa.) equipped with a G-M scanning head, model S-3, serial No. 214 (Nuclear Research and Development, Inc., St. Louis, Mo.), mounted on a model No. SC5, serial No. 31, base and set for beta-gamma measurement. Readings were taken for 1 min and were recorded as counts per minute. Standardization was with National Bureau of Standards (NBS) Radium D + E No. 1162. Products were blended until they became homogeneous, and they were weighed into stainless-steel planchets ($\frac{1}{4}$ in. high and 1 in. in diameter) in 3-g amounts for scaling.

Additional scaling of metal disks from the tin containers and the jar closures and the scaling of ash samples of the products were conducted at the FDA laboratories in Washington, D. C. Activities were determined with a Tracerlab thin window (thickness about 1.3 mg/cm^2) G-M tube in conjunction with a Tracerlab Superscaler. The ash samples were weighed into stainless-steel planchets ($\frac{1}{4}$ in. high and 1 in. in diameter), distributed evenly over the bottom, and stored in desiccators so they would not be disturbed between successive readings. The standard used for conversion to disintegrations per minute was NBS No. 1161, with a value, corrected to August 1955, of 125.4 dis/sec.

CHAPTER 4

RESULTS AND DISCUSSION

The yield of the open shot was approximately one and one-half times the 20 kt considered as nominal. Under the exaggerated exposure conditions used for some samples, blast over-pressures were as high as 45 psi, neutron densities were in the range of 10^{11} to 10^{13} per square centimeter, and gamma-radiation levels were in the range of 45,000 to 70,000 r. Comparative blast and radiation levels for nuclear devices are discussed in reference 1. Immediate postshot observations of samples located in structures at 4700 ft and farther from Ground Zero were made within 6 hr after the nuclear detonation. Recovery of all samples from these locations was accomplished within three days, and buried and sheltered samples at closer distances were recovered on the third and fourth days after the blast. Because of the functional design of the canned-food tests, the results are reported under the individual test headings.

4.1 TEST 1: GENERAL TEST ON CONTAINER DAMAGE AND PHYSICAL AND ORGANOLEPTIC EFFECTS ON PRODUCTS

4.1.1 Emergency Underground Shelters

During the approximately nominal shot, representative tin and glass containers were located in the rear corner of a basement exit type shelter at about $\frac{1}{4}$ mile from Ground Zero. All containers survived the severe blast pressure and showed no induced radioactivity, al-though moderate to severe paneling was caused on the bodies of No. 10- and 46-oz cans (Fig. 4.1). In the open shot similar foods in tin and glass were placed in an open case within a group personnel shelter at 1050 ft from Ground Zero (Table 2.3). This shelter was designed to withstand approximately 100 psi pressure and was located 5 to 6 ft below ground level. In this instance there was no substantial overpressure or radiation flux within the shelter, and the foods were undamaged and showed no induced radioactivity. *These results, in conjunction with those to follow, indicate that canned foods are suitable for use when located in shelters that are effective in protecting personnel against excessive radiation or blast damage.*

4.1.2 Buried Cases at 1270 Ft from Ground Zero

At a 1270-ft distance and under the exposure conditions described in Sec. 2.3, the con-tainers were subjected to maximum radiation and blast overpressures (see introductory re-marks for this chapter). This deliberately exaggerated exposure was used to determine the gross effects that might be encountered, and samples so exposed were subjected to radiologi-cal scaling for induced activity, animal feeding tests to determine safety on long-term ingestion, and acceptance tests for flavor, texture, or other observable characteristics. The results of animal feeding tests are treated separately in Test 5 (Sec. 4.5). The other test results follow.
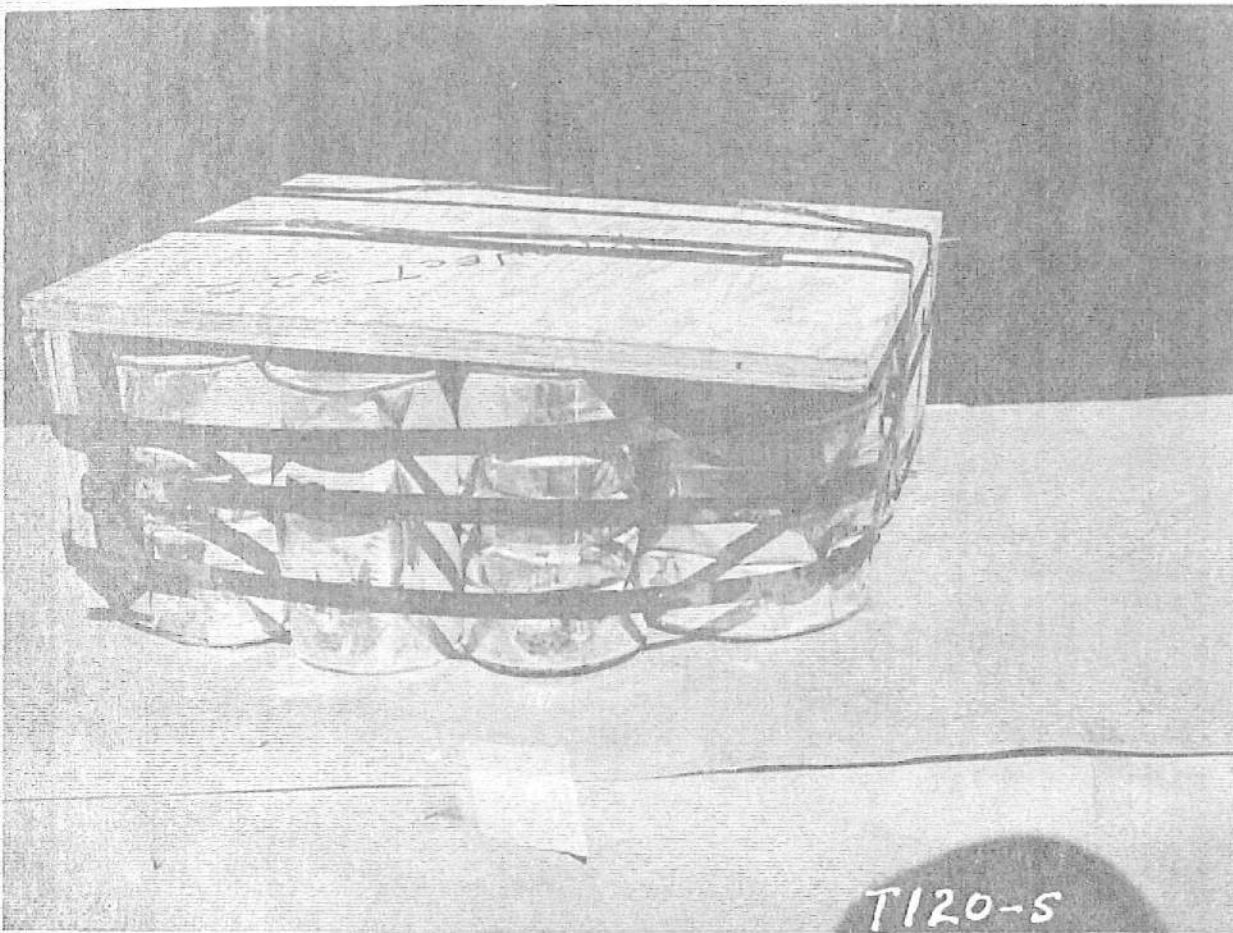
Fig. 4.1—Strapped cans following exposure in a basement exit type shelter about $\frac{1}{4}$ mile from Ground Zero of the approximately nominal shot.

(a) *Physical Effects on Containers.* As a result of the pressure surge (about 45 psi) at 1270 ft from Ground Zero, 15 to 20 per cent of the glass containers were broken. Most of these breaks were due to mechanical crushing (Fig. 4.2), and a smaller number were due to hydraulic surge knocking out a small wall hole (Fig. 4.3). In the last instance the case bottom or earth support probably allowed the initial, rapid, downward movement of the jar necessary for this phenomenon. An interesting and useful effect observed here was the coloration of the glass containers subjected to a high radiation dose. This is technically known as "graying" or "solarization" and is immediately evident to the casual observer as a visual "dosimeter" of radiation (Fig. 4.4). As will be pointed out later, the contained food may be entirely satisfactory for use, but the coloration serves as an indicator of previous exposure to high radiation.

In a similar manner the tin containers showed evidence of the high overpressure (about 45 psi) by various degrees of crushing (sharp deformation) of the can body and double seams. Figure 4.5 shows the type and maximum degree of can deformation. This type of damage was observed in 25 to 50 per cent of the cans. Deformation of this type is not expected in normal handling and serves as an index of high blast pressures and possible high radiation exposure. However, the food in the cans may be entirely satisfactory.

(b) *Induced Radioactivity of Critically Exposed Foods. Background and Methods.* Samples exposed to maximum radiation effects at 1270 ft from Ground Zero (see Sec. 2.3 and the introductory remarks for this chapter) were recovered, and their induced radioactivity was determined in a preliminary manner by scaling 3-g samples of the comminuted contents of the containers. Samples of 54 of the total of 68 products, including all those showing an appreciable level of radioactivity, were sent to the Research Laboratory of the National Canners Association, Washington, D. C., where they were ashed and their induced radioactivity was determined on 25- and 50-mg samples of the ashed product. The radioactivity of the containers was also determined and is discussed in Sec. 4.1.2c.

All containers were carefully washed before opening. The entire contents of each container was homogenized by blending for several minutes in a Waring Blendor, except in the case of the shrimp packed in brine, in which the brine was discarded before blending. To obtain sufficient material, it was necessary to ash 25 g of the blended product, and, because of this large amount, an overnight heating period was usually required to obtain an ash of satisfactory appearance. Radioactivities were determined on both 25- and 50-mg portions of the ash. When expressed on a unit weight basis, the results from the 50-mg samples averaged 7 per cent (range 0 to 22 per cent) less than those from the 25-mg samples; hence, to minimize errors due to self-absorption, only those from the 25-mg samples are included in this report. Ash samples were counted on the instrument described in Sec. 3.2 for a 10-min period, and counts were made at two to three weeks, one month, and three and one-half months after exposure.

Control samples for 14 of the most active products were also ashed, and their natural radioactivities were determined in the same manner. The highest control sample tested had an activity of 4 c/m/g when calculated on a wet-weight basis, and it was felt unnecessary to make corrections for such insignificant counts.

Results. All products exposed by burial at 1270 ft were scaled as wet samples at 112 hr after the shot (H + 112 hr) and at further intervals on the instrument described in Sec. 3.2. Tables 4.1 and 4.2 report activities of the wet samples as counts per minute per gram, but 3-g samples were actually scaled. Limited scaling of 1-g samples gave values approximately two and one-half times as great as those listed. Because of this self-absorption the results in Tables 4.1 and 4.2 should be treated as comparative rather than absolute values.

Part A of Table 4.3 presents the results obtained on the 15 most radioactive foods as first determined on the ash some 14 to 20 days after their exposure. These are listed in order of decreasing activity, and all counting results have been calculated to a wet-weight basis. For the first and second readings, these have been expressed in counts per minute per gram, disintegrations per minute per gram, microcuries per gram, microcuries per average serving,

Fig. 4.2—Sample of maximum damage from mechanical crushing to a case of 28-oz jars exposed in trenches at 1270 ft from Ground Zero.
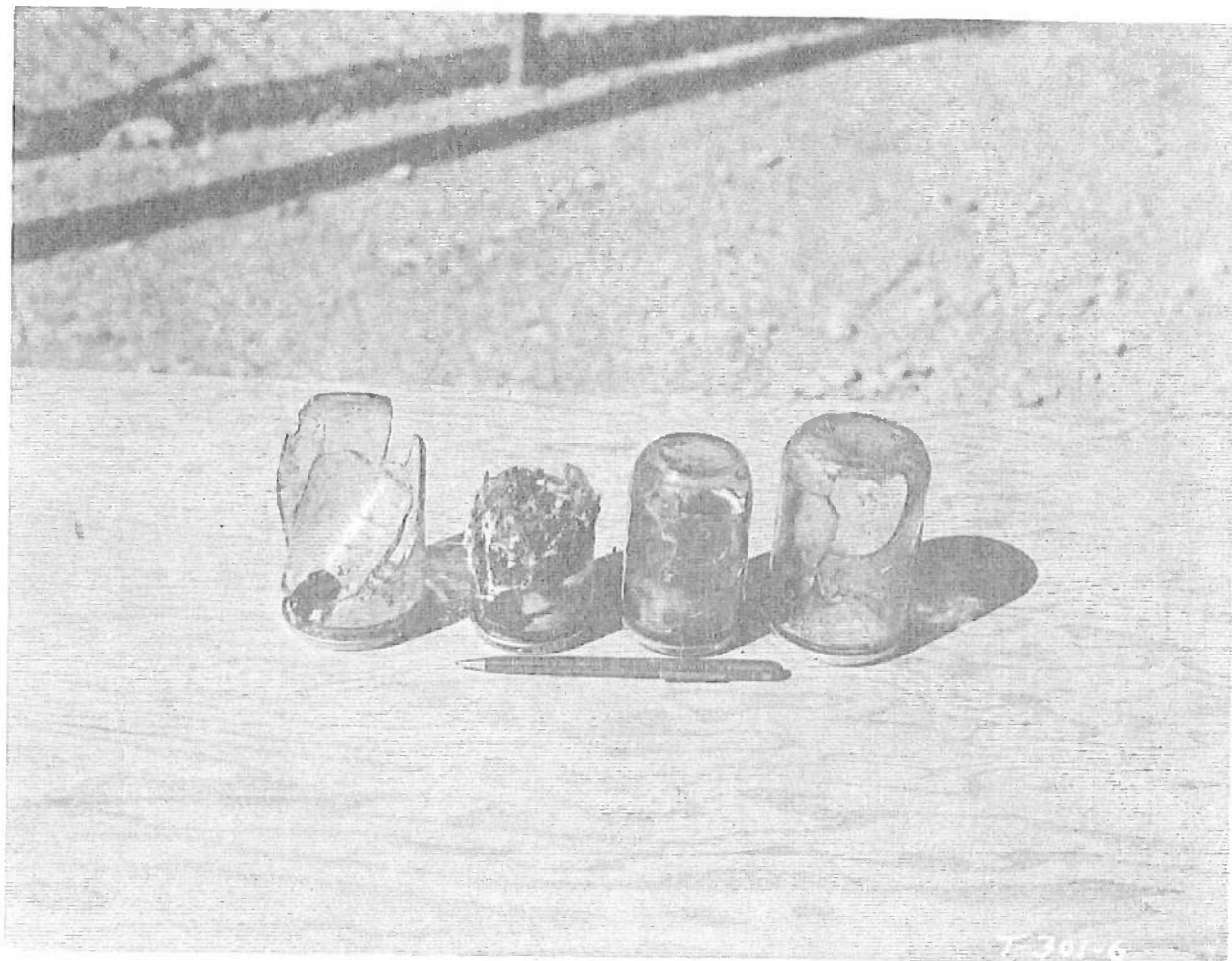
Fig. 4.3—Representative jars, showing mechanical crushing (two at left) and hydraulic surge (two at right), selected from the 15 to 20 per cent that suffered such damage after exposure in buried cases at 1270 ft from Ground Zero.
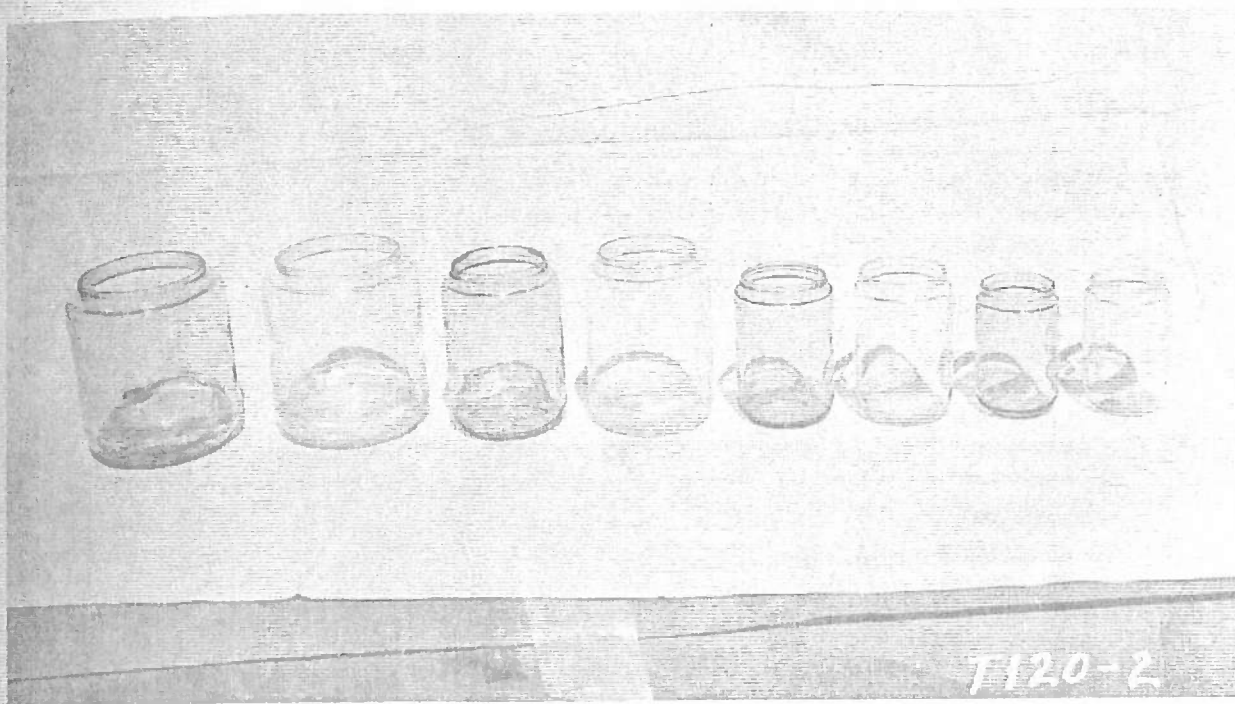
Fig. 4.4—Graying, or solarization, of some glass containers subjected to high radiation dose at 1270 ft from Ground Zero. The clear jars in alternate positions are the controls.
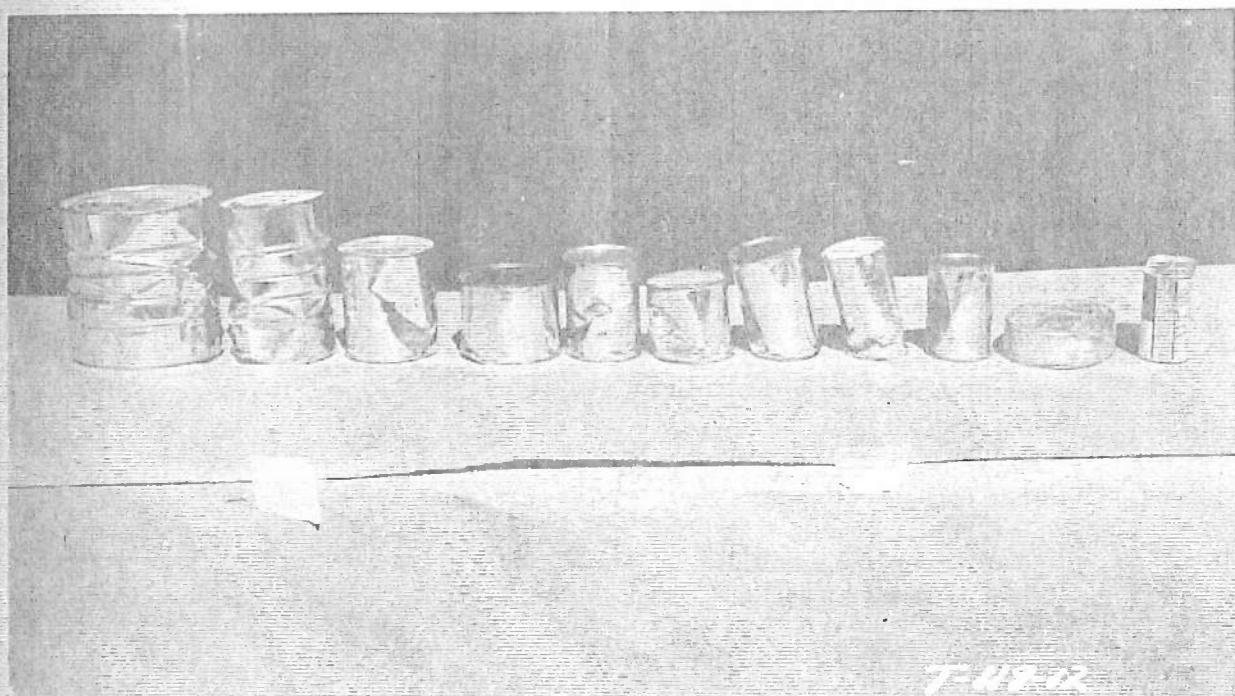
Fig. 4.5—Representative cans, showing maximum damage from mechanical crushing, selected from the 25 to 50 per cent that suffered such damage after exposure in buried cases at 1270 ft from Ground Zero.

| | Counts per minute per gram* | | |
Product	H+112 to 118 hr	H+151 to 156 hr	H+202 to 207 hr†
Corn (whole kernel)	1107	265	143
Peas	939	358	158
Green beans	890	210	83
Beets	572	133	82
Sauerkraut	1339	229	79
Sweet potatoes	273	119	53
Peaches	130	14	
Pineapple	101	4	3
Pears	45	0	
Applesauce	106	19	
Grapefruit	137	36	27
Blueberries	15	8	19
Blackberries	100	61	
Purple plums	36	81	
R.S.P. cherries	88	52	37
Tomato juice	474	98	30
Orange juice	73	47	
Pineapple juice	46	27	
Salmon	2747	2041	1094
Tuna	1915	1052	627
Sardines in oil (scored)	2386	1555	1051
Sardines in oil (unscored)	2285	1487	1021
Sardines in tomato sauce	1621	1014	1149
Shrimp	3099	1039	402
Luncheon meat	2633	706	320
Hamburgers	1259	594	376
Frankfurters	2157	535	236
Chicken (boned)	1660	654	367
Pork and beans	1212	449	216
Beef stew	1683	551	188
Spaghetti	1515	438	114
Corned beef hash	1672	413	185
Tomato soup (conc.)	1389	288	76
Vegetable-beef soup (conc.)	1302	292	95
Mushroom soup (conc.)	1401	304	196
Mushroom soup (ready to serve)	1189	305	122
Consommé (conc.)	1152	292	136
Strained spinach	838	218	112
Strained carrots	717	147	62
Strained apricots and apples	286	76	50
Strained bananas	119	14	
Strained chicken soup	649	166	69
Strained lamb and vegetables	830	218	95
Strained liver and vegetables	889	317	204
Strained vanilla custard	798	317	217
Strained beef	674	424	297
Evaporated milk	879	546	583
Mixed vegetables (feeding test)	1688‡	92	78

* Scaled on a 3-g wet-weight sample.

† Results on duplicate container.

‡ H+82 hr.

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Table 4.2 — RADIOACTIVITIES ON UNASHED FOODS IN GLASS CONTAINERS

Product	Counts per minute per gram*		
	H+ 112 to 118 hr	H+ 151 to 156 hr	H+ 202 to 207 hr†
Green beans	668	137	
Beets	656	120	42
Carrots	469	99	
Fruits for salad	55	23	
Apple juice	29	0	
Grape juice		24‡	
Shrimp	2993	365	543
Frankfurters	1489	899	199
Pork and beans	1061	496	218
Catsup	927	438	65
Chicken ravioli	811	296	117
Strained spinach	349	123	66
Strained carrots	437	133	54
Strained apricots and apples	45	24	70
Strained bananas	92	47	
Strained chicken soup	656	178	70
Strained lamb and vegetables	570	150	108
Strained liver and vegetables	835	269	202
Strained vanilla custard	557	244	157
Strained beef	1091	573	427
Mixed vegetables (feeding test)		94	95

*Scaled on a 3-g wet-weight sample.

† Results on duplicate container.

‡ H+ 177 hr.

Table 4.3.—INDUCED RADIOACTIVITIES* IN EXPOSED FOODS, MOST ACTIVE AND LESS ACTIVE PRODUCTS

Product	Container	Container net wt., g	Wt. of av. serving, g	Ash, %	After two to three weeks						After one month						After three and one-half months	
					Days after exposure	Counts/ min/g	Dis/ min/g†	Micro-curies/g ×1000	Micro-curies/av. serving	Micro-curies/ container	Days after exposure	Counts/ min/g	Dis/ min/g†	Micro-curies/g ×1000	Micro-curies/av. serving	Micro-curies/ container	Days after exposure	Counts/ min/g
Part A. Most Active Products																		
Sardines in oil (scored)	Tin	92	60	3.16	15	2257	6044	2.72	0.163	0.250	35	989	2637	1.19	0.0714	0.109	103	77.2
Sardines in oil (unscored)	Tin	92	60	3.22	18	2112	5656	2.55	0.153	0.235	35	982	2615	1.18	0.0708	0.109	103	47.7
Sardines in tomato sauce	Tin	425	106	2.57	18	1515	4057	1.83	0.194	0.778	35	711	1893	0.853	0.0904	0.363	103	65.7
Salmon	Tin	454	113	2.73	20	1290	3455	1.56	0.176	0.708	35	659	1755	0.791	0.0893	0.359	103	31.4
Evaporated milk	Tin	412		1.63	14	1257	3366	1.52		0.626	32	586	1561	0.703		0.290	95	55.5
Tuna	Tin	198	100	2.28	20	1157	3098	1.40	0.140	0.277	34	622	1656	0.746	0.0746	0.148	99	32.4
Shrimp	Glass	1208	65	4.05	20	993	2659	1.20	0.0780	0.144	34	569	1515	0.683	0.0444	0.0820	96	170
Strained beef	Glass	99		1.06	15	836	2239	1.01		0.100	33	372	991	0.446		0.0442	96	25.5
Catsup	Glass	397		4.22	15	768	2057	0.927		0.368	33	586	1561	0.703		0.279	96	337
Shrimp	Tin	1428	65	4.15	20	748	2003	0.902	0.0586	0.128	34	446	1187	0.535	0.0348	0.0760	99	55.6
Luncheon meat	Tin	341	85	4.21	20	700	1875	0.845	0.0718	0.288	35	402	1070	0.482	0.0410	0.164	103	59.4
Chicken (boned)	Tin	142		1.47	20	698	1869	0.842		0.119	34	358	953	0.429		0.0609	99	36.2
Hamburgers	Tin	319	106	1.62	18	679	1818	0.819	0.0868	0.261	35	278	740	0.333	0.0353	0.106	103	19.5
Strained liver and vegetables	Glass	135		1.02	15	577	1545	0.696		0.0940	33	285	759	0.342		0.0462	96	57.1
Pork and beans	Glass	450	119	1.69	18	577	1545	0.696	0.0828	0.313	35	335	892	0.402	0.0478	0.181	103	82.9
Part B. Less Active Products																		
Beef stew	Tin			1.64	18	574	1537	0.692			34	324	863	0.389			99	61
Strained vanilla custard	Tin			0.86	15	564	1510	0.680			33	273	673	0.327			96	49
Strained beef	Tin			0.99	15	549	1470	0.662			33	253	673	0.303			96	18
Pork and beans	Tin			1.60	20	507	1358	0.612			33	320	852	0.383			96	84
Corned beef hash	Tin			1.72	15	487	1304	0.588			35	254	676	0.304			103	50
Frankfurters	Tin			2.34	15	463	1293	0.583			35	228	607	0.273			103	57
Strained liver and vegetables	Tin			0.96	15	476	1275	0.574			33	225	599	0.270			96	49
Mushroom soup	Tin			2.02	14	441	1181	0.532			33	237	631	0.284			95	74
Frankfurters	Glass			1.92	20	415	1111	0.500			35	232	618	0.279			103	33
Strained vanilla custard	Glass			0.83	15	414	1109	0.499			33	196	522	0.235			96	29
Mushroom bisque	Tin			1.63	20	405	1086	0.498			33	285	759	0.342			96	115

Table (continued). Columns are unlabeled on this page; values are listed as printed. Superscript symbols (‡, etc.) follow the footnote key below.

Food	Container											
Strained vanilla custard	Glass	0.83	15	414	1109	0.499	33	196	522	0.235	96	29
Mushroom bisque	Tin	1.63	20	405	1085	0.488	33	285	759	0.342	96	115
Ravioli‡	Glass	1.38	15	393	1052	0.474	35	221	589	0.266	103	60
Peas	Tin	1.16	15	387	1036	0.467	34	182	485	0.218	99	38
Spaghetti	Tin	2.04	15	379	1015	0.457	35	250	666	0.300	103	93
Beef consommé	Tin	1.96	14	343	919	0.414	32	192	511	0.230	95	46
Corn (whole kernel)	Tin	1.16	18	326	873	0.393	34	175	466	0.210	99	32
Green beans	Tin	1.37	15	299	801	0.361	34	199	530	0.239	103	97
Tomato soup	Tin	2.62	15	296	793	0.357	33	135	360	0.162	96	9
Strained vegetables with lamb	Tin	0.98	15	295	790	0.356	33	169	450	0.203	95	49
Strained spinach	Tin	1.26	14	284	761	0.342	32	180	479	0.216	95	54
Beets	Tin	1.46	18	272	728	0.328	34	203	541	0.243	99	107
Strained chicken	Tin	0.94	14	260	696	0.313	33	130	346	0.156	95	43
Strained vegetable soup	Tin	2.40	20	257	688	0.310	33	188	501	0.226	96	79
Strained vegetable and beef soup	Tin	0.98	15	240	643	0.289	33	122	325	0.146	95	32
Strained chicken soup	Glass	1.02	15	238	637	0.287	33	114	304	0.137	96	36
Strained lamb and vegetables	Glass	0.78	20	235	629	0.283	34	138	367	0.165	99	20
Mixed vegetables (feeding test)	Tin	0.93	14	232	621	0.280	32	159	423	0.191	95	66
Strained carrots	Tin	1.27	18	232	621	0.280	34	163	434	0.196	103	72
Beets	Glass											
Strained carrots	Glass	0.90	14	212	568	0.256	33	116	309	0.139	95	36
Strained spinach	Glass	1.16	14	207	554	0.250	32	103	274	0.123	95	22
Mixed vegetables (feeding test)	Glass	0.70	20	181	485	0.219	34	106	282	0.127	99	18
Sauerkraut	Tin	1.55	20	158	423	0.191	34	129	344	0.155	99	49
Sweet potatoes	Tin	0.48	20	153	410	0.185	34	89	237	0.117	99	14
Strained apricots and apples	Tin	0.47	14	140	375	0.169	33	63	168	0.076	95	9
Cherries (No. 10 can)	Tin	0.29	18	108	289	0.130	35	59	157	0.071	103	18
Tomato juice	Tin	1.18	20	100	268	0.121	33	68	181	0.081	96	29
Grapefruit sections	Tin	0.32	15	82	220	0.099	34	65	173	0.078	99	27
Blueberries	Tin	0.14	18	71	190	0.086	34	22	59	0.027	99	10
Pineapple slices§	Tin	0.35	15	45	121	0.055	34	28	75	0.034	99	13

* Measured in 25-mg ash samples and calculated on wet-weight basis.
† Counts per minute per gram × 2.678.
‡ Counts per minute per gram × 2.663.
§ Drained weight.

and microcuries per container net weight. The results from the third reading are given only in counts per minute per gram. Also included are the container net weight, weight of an average serving of the product, the percentage of ash, and the experimental half life as approximated from the decay curves of the induced radioactivities.

The results on all the remaining, less active products are given in Part B of Table 4.3. These are expressed similarly to the most active products except that data relating to net weights and average servings have been omitted.

At the first determination the results ranged from 45 c/m/g in a sample of pineapple slices to 2257 c/m/g in sardines. All the fish products tested were found among the 15 most active products. The remainder of the 15 were meat products, catsup, evaporated milk, strained liver and vegetables, and pork and beans.

The products showing less activity might be divided into two groups of activity, intermediate and low. The products included in the intermediate group (400 to 570 c/m/g) were beef stew, vanilla custard, strained beef, pork and beans, corned beef hash, frankfurters, strained liver and vegetables, and mushroom soup.

The group less active than 400 c/m/g at the first reading was made up of fruits, vegetables, soups, and juices. Tomato juice was found among the least active of the products tested, having an activity of 100 c/m/g. This may be compared with tomato catsup, which was found to have an activity of 768 c/m/g.

Within one month after exposure the most active products had decayed to roughly 50 per cent of their activity as first measured, and after three and one-half months all the products of this group, with the exception of catsup and one shrimp sample, had less than 100 c/m/g.

In an effort to identify the principal isotopes responsible for the radioactivity, the decay curves for the 15 most active products in Table 4.3 were plotted and the half lives determined graphically. The last column in the table gives the half lives determined in this manner. Four such curves are illustrated in Figs. 4.6 and 4.7. In these the counts per minute per gram were plotted on a logarithmic scale against time in days. The line formed by the last two points was extrapolated to zero time, and the indicated half life was determined from the slope of this line. The data are insufficient for more than a rough approximation in most cases. With some products, e.g., the sardines and salmon illustrated in Figs. 4.6 and 4.7, the activity was evidently due largely to a single isotope, and reasonable approximations were obtained. In addition to sardines in scored cans (Fig. 4.6) and salmon (Fig. 4.7), sardines in unscored cans, tuna, and strained beef in jars gave curves which closely approximated straight lines. Most of the remaining curves were rather similar in shape to the curve for shrimp illustrated in Fig. 4.6. Catsup, shown in Fig. 4.7, gave the longest apparent half life (77 days) of the 15 products.

Discussion. There appears little doubt that P^{32} is the isotope responsible for the major part of the activity in nearly all the more radioactive foods when measured two to three weeks after their exposure. This isotope can be formed from the natural isotope of phosphorus by neutron capture. It has a half life of 14.3 days, and this figure is rather closely approximated by several of the values in the last column of Table 4.3. Tables of radioactive isotopes yield no other reasonable possibilities with half lives near this figure. Furthermore, the order of the products with respect to induced radioactivity is very similar to their order as to phosphorus content.

Eleven of the most active products in Table 4.3 are listed in Table 4.4, together with average values for phosphorus content collected from various sources.

Catsup is omitted from Table 4.4 since its activity is evidently due to species other than P^{32}. The indicated activity per milligram of phosphorus shown in the last column was computed by using the activities at two to three weeks and the average phosphorus contents shown. These values average 0.62×10^{-3} µc/mg and show surprisingly little variation, in view of the approximate data.

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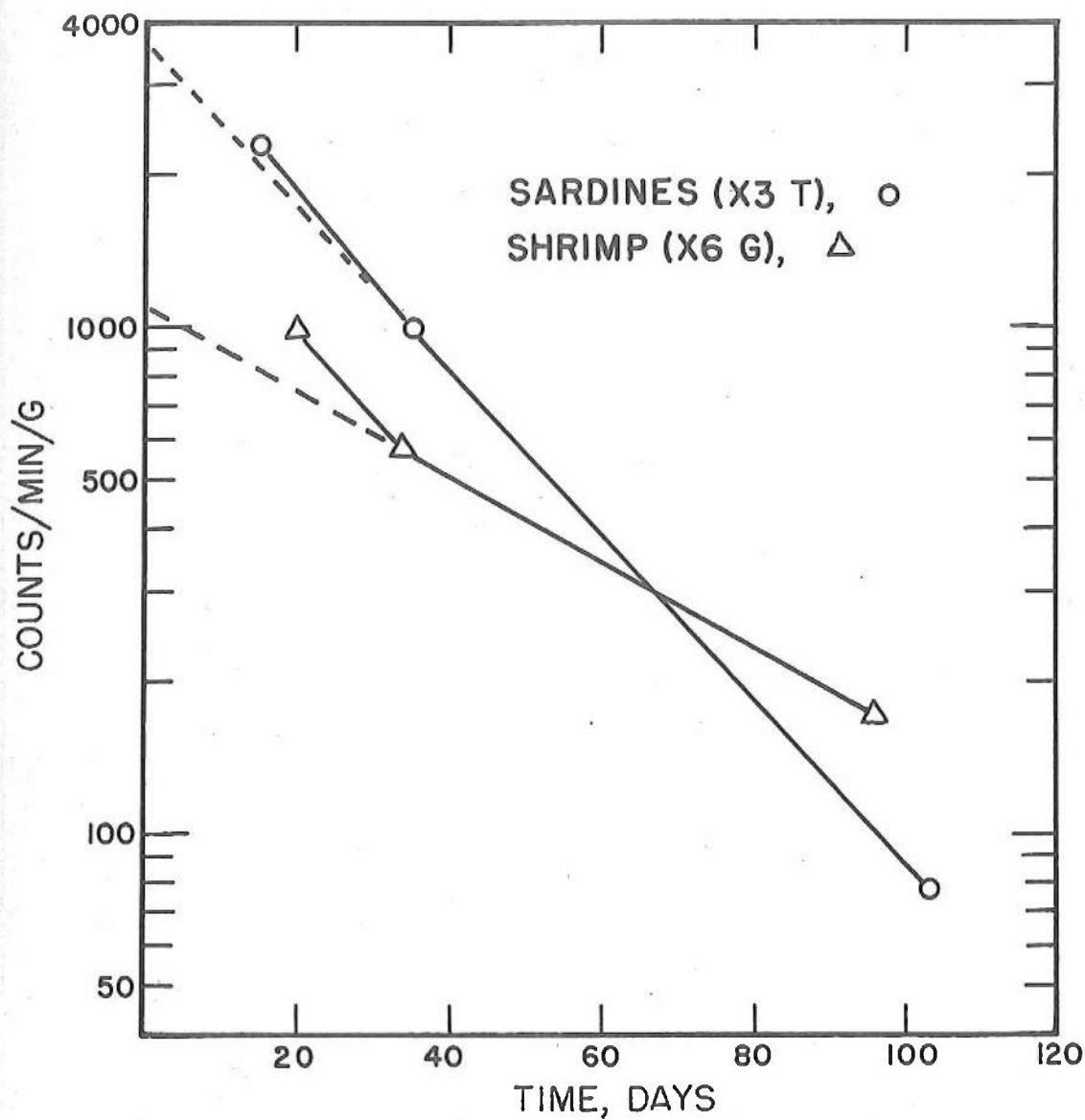
Fig. 4.6—Decay curves for sardines and shrimp.
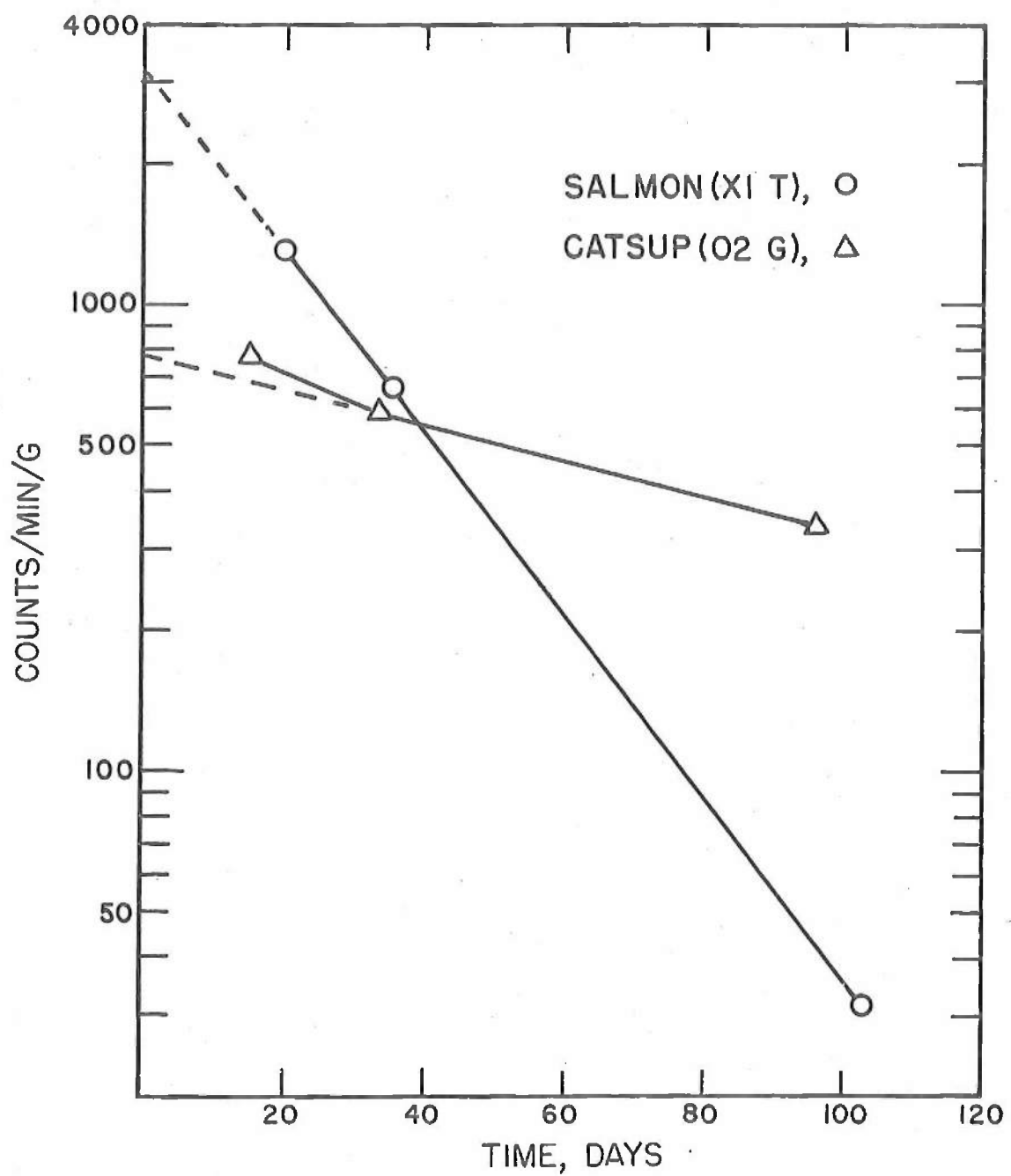
Fig. 4.7—Decay curves for salmon and catsup.

Table 4.4—AVERAGE VALUES FOR PHOSPHORUS CONTENT OF SOME OF THE EXPOSED FOODS

Product	Phosphorus, mg/g	Activity at two to three weeks, $\mu c/g \times 1000$	Indicated activity of phosphorus, $\mu c/mg \times 1000$
Sardines in oil (scored)	4.34	2.72	0.63
Sardines in oil (unscored)	4.34	2.55	0.59
Sardines in tomato sauce	3.65	1.83	0.50
Salmon	2.92	1.56	0.53
Evaporated milk	1.95	1.52	0.78
Tuna	2.24	1.40	0.62
Shrimp (in glass container)	1.49	1.20	0.81
Strained beef	1.50	1.01	0.67
Shrimp (in tin container)	1.49	0.902	0.61
Luncheon meat	1.70	0.845	0.50
Chicken (boned)	1.48	0.842	0.57

The half life for the radioactive products in catsup is the only one differing markedly from the other values listed in Part A of Table 4.3. The experimental value of 77 days suggests S^{35} (half life 87.1 days) as a reasonable possibility. This isotope can be formed from the common isotope of chlorine, Cl^{35}. The sodium chloride content of catsup varies from about 1.5 to 3 per cent. Other products in Part A of Table 4.3 containing appreciable salt showed half lives somewhat longer than 14 days. For example, shrimp are packed in brine, and the first of the shrimp samples gave a plotted half life of 36 days. With one exception, all the less active products listed in Part B of Table 4.3 gave experimental half lives between 14 and 87 days, and it seems likely that in most of these cases the activity came from P^{32} and S^{35} in varying proportions. One product, tomato soup, gave a half life of 105 days.

Although the instrument used probably detected only a small percentage of the soft beta activity from S^{35}, it seems probable that this isotope can be eliminated from considerations relating to the use of these products as emergency rations. National Bureau of Standards Handbook 52 gives the following pertinent constants[2] for estimating the maximum permissible intake of S^{35} into the body.

Maximum permissible amount
   in total body   100 μc
Critical organ   Skin
Half life
   Physical   87.1 days
   Biological   22 days
   Effective   18 days
Fraction reaching critical organ
   by ingestion   0.08

Only in the less active products did S^{35} contribute an appreciable share of the total activity of the product, with the exception of the catsup. The possibility of injury from this source is further reduced by its short effective half life and the fact that the critical organ takes up only a small fraction of the total amount ingested. In view of these considerations, P^{32} is taken here as the significant species in estimating the degree of hazard involved in the use of critically exposed foods.

With respect to their induced radioactivity, it can be said that all foods tested were within acceptable risk levels for emergency use within two weeks after their exposure. The "Radiological Health Handbook"[3] suggests the emergency levels given in Table 4.5 for food and water immediately following a nuclear explosion. Two weeks after exposure the most active of the foods tested contained 2.7×10^{-3} $\mu c/g$, which is well within the suggested acceptable

risk level for a 30-day consumption period, although somewhat greater than the level indicated as a preferable risk. Only a few of the foods tested approached the 3×10^{-3} level of activity. Of the 54 foods tested, all but eight had activities less than 1.0×10^{-3} μc/g two weeks after their exposure.

Table 4.5 — BETA ACTIVITY LEVELS

Consumption period, days	Microcuries per cubic centimeter
Preferable Risk	
10	3.5×10^{-3}
30	1.1×10^{-3}
Acceptable Risk	
10	9×10^{-2}
30	3×10^{-2}

It should be noted that the levels given in Table 4.5 were suggested as a guide for emergency use only and should not be confused with tolerances permissible for continuous exposure. National Bureau of Standards Handbook 52 gives 2×10^{-4} μc/ml (of water) as the maximum permissible amount of P^{32} for continuous exposure in occupational or industrial situations.[2] When tested two weeks after their exposure, all but eight of the foods were still above this level of activity. Approximately one month after exposure, 17 samples had fallen below this level, and by three and one-half months all but two samples were below this level. In an emergency situation it is to be presumed that the use of radioactive foods would be limited to short periods. Furthermore, activity of the radioactive source would not remain constant, as it might in an industrial situation, but would decline owing to the natural decay of the radioactive isotopes. In the following discussion an attempt is made to estimate the hazard involved in such a situation.

At the first scaling of the ashed products 14 to 20 days after their exposure, the average activity of the phosphorus in the most active foods was estimated previously to be 0.62×10^{-3} μc/mg. If this is taken as the activity after 17 days, then the initial activity is 1.4×10^{-3} μc/mg. With data[2] from NBS Handbook 52 it is possible to estimate the accumulation of P^{32} in the body, assuming that all phosphorus in the diet had an initial activity of 1.4×10^{-3} μc/mg. The handbook indicates that practically all (92 per cent) the phosphorus in the total body is in the bone. Other pertinent constants are as follows:

Maximum permissible amount in total body	10 μc
Daily intake of element	1.4 g
Half life	
Physical	14.3 days
Biological	1200 days
Effective	14 days
Fraction reaching critical organ (bone) by ingestion	0.2

Thus 280 mg of phosphorus is added to the bone each day, and this amount would have had an initial activity of 0.39 μc. If the effective half life were taken equal to the physical half life and if the food were placed in use immediately following the explosion, the total accumulation in the bone would be as given in Table 4.6. The maximum accumulation of 3 μc, occurring after 20 days, is well below the 10 μc indicated as permissible.[2] Shrimp (in jars) gave the

greatest indicated activity per milligram of phosphorus (0.81×10^{-3}). If this value is used in the calculations rather than the average value, the maximum accumulation is of the order of 4.2 μc.

Table 4.6 — ACCUMULATION OF PHOSPHORUS IN BONE

Consumption period, days	Fraction of original activity remaining	Accumulation of P^{32} in bone, μc
5	0.785	1.5
10	0.616	2.4
15	0.484	2.8
20	0.379	3.0
25	0.298	2.9
30	0.234	2.7

In the preceding discussion the induced radioactivity due to isotopes having shorter half lives has not been considered. Extrapolation of semiquantitative scaling data on wet samples, Tables 4.1 and 4.2, and similar data collected by the Food and Drug Administration during an earlier shot indicate that in a few samples the initial activity may have reached the order of one hundred thousand or more counts per minute per gram. This high initial activity is probably due largely to Na^{24}, which has a half life of 15 hr, and possibly K^{42}, which has a half life of 12.4 hr. The maximum permissible amount of Na^{24} in the body is given as 15 μc and that for K^{42} as 20 μc (reference 2). If these foods were used within one or two days after the blast, it is possible that the maximum limit for Na^{24} might be exceeded. It must be remembered, however, that these foods were exposed under very critical conditions, and, because of the dangerous level of activity in the area surrounding their exposure site, they would not be accessible to personnel in the normal course of events until three or more days after the explosion. After this interval of three or four days, induced radioactivity due to Na^{24} and K^{42} would decline to a fraction of its initial value, and the foods would be usable as emergency rations with little, if any, real hazard from Na^{24} or K^{42}.

It should be emphasized that the discussion in this section has been confined largely to those samples critically exposed at 1270 ft. There was no induced radioactivity in samples exposed in an aboveground shelter at 3750 ft. Foods recovered from the aboveground shelter at 2250 ft were found to be only slightly radioactive three days after the blast. Foods recovered from shelters and other locations in which the radiation level had approached lethal or slightly sublethal dosages were found to be safe for emergency use. *In other words, any foods stored in a shelter in which personnel have survived the explosion should be safe for emergency use. Such foods as might be recoverable from critically exposed areas within the zone of "complete" destruction could be pressed into emergency use after about three or four days.*

(c) *Induced Radioactivity of Critically Exposed Containers. Background and Methods.* Tables 4.7 and 4.8 list the induced radioactivities of the metal containers and glass jars and closures exposed at 1270 ft from Ground Zero. The activities recorded in these tables were determined on the containers of the foods whose induced radioactivities are listed in Table 4.3, except that, in the last column of Table 4.8, the activities of the empty glass jars after 208 hr refer to determinations made on duplicate jars exposed at the same site.

Readings were made on metal disks, 0.57 in. in diameter, taken from the can or jar closure by means of a special cutting punch. For plain (unenameled) cans, one disk was punched from each end. Enameled cans were punched twice at each end; thus one disk could be scaled with the enamel on and the other after the enamel had been removed. Cans with enameled ends and plain bodies were punched twice at each end and once on the body of the container. The metal closures for the glass jars were punched twice, the activity of one disk being read with the enamel on, the other after the enamel had been removed. Two readings, at three to four weeks and at two

Table 4.7—INDUCED RADIOACTIVITIES IN EXPOSED CANS
(Inner Surface of Metal Disk, 0.57 In. in Diameter)

Product in cans when exposed	Can size	Type of enamel* on ends	Disk† source and treatment	Days after exposure	Counts/min	Days after exposure	Counts/min
Grapefruit	303 × 406	None	C	27	51	67	68
			P		147		111
Shrimp	211 × 300	"C"	C+	26	1313	63	1062
			C−		112		70
			P+		1675		1460
			P−		47		28
Sweet potatoes	404 × 307	San.	C+	26	165	64	85
			C−		124		65
			P+		83		51
			P−		66		32
			Body		191		112
Salmon	301 × 411	San.	C+	28	104	68	55
			C−		93		53
			P+		37		25
			P−		33		15
			Body		64		34
Sardines in tomato sauce	1 lb (oval)	San.	C+	32	79	68	54
			C−		75		45
			P+		47		25
			P−		42		23
Mixed vegetables (feeding test)	303 × 406	"C"	C+	26	86	64	46
			C−		75		32
			P+		169		95
			P−		133		58
			Body		76		45
Pork and beans	300 × 407	"C"	C+	22	309	63	157
			C−		184		69
			P+		140		79
			P−		56		20
Boned chicken	303 × 108	"C"	C+	22	332	64	265
			C−		65		41
			P+		420		326
			P−		89		58
Frankfurters	300 × 407	"C"	C+	28	833	67	606
			C−		92	68	46
			P+		687		529
			P−		63		36
Tuna	307 × 113	San.	C+	26	83	63	45
			C−		86		45
			P+		82		64
			P−		86		47
Strained apricots and apples	202 × 214	None	C	21	105	61	58
			P		60		32
Pineapple	401 × 411	None	C	27	22	64	15
			P		94		66

Table 4.7 — (Continued)

Product in cans when exposed	Can size	Type of enamel* on ends	Disk† source and treatment	Days after exposure	Counts/ min	Days after exposure	Counts/ min
Strained carrots	202 × 214	"C"	C+	21	121	61	84
			C−		98		52
			P+		72		39
			P−		51		27
R.S.P. cherries	603 × 700	San.	C+	28	18	67	7
			C−		14		7
			P+		104		62
			P−		98		57
Blueberries	300 × 407	San.	C+	26	40	64	24
			C−		43		28
			P+		97		58
			P−		99		62
Peas	303 × 406	"C"	C+	27	464	64	406
			C−		68		38
			P+		570		452
			P−		98		63
Strained lamb and vegetables	202 × 214	"C"	C+	22	147	62	108
			C−		105		58
			P+		80		56
			P−		45		25
Mushroom soup (ready to serve)	211 × 414	"C"	C+	22	264	62	173
			C−		108		57
			P+		158	63	84
			P−		31		13
			Body		239		161
Spaghetti	300 × 407	"C"	C+	28	325	67	259
			C−		80		53
			P+		150		110
			P−		29		18
			Body		198		156
Sauerkraut	401 × 411	None	C	42	87	64	61
			P		30		31
Strained liver and vegetables	202 × 214	San.	C+	22	99	62	69
			C−		112		57
			P+		50		37
			P−		49		36
Tomato juice	404 × 700	San.	C+	22	130	63	63
			C−		107		53
			P+		25		14
			P−		16		6
			Body		182		131
Strained vanilla custard	202 × 214	San.	C+	22	104	62	67
			C−		95		56
			P+		74		50
			P−		53		30

Table 4.7 — (Continued)

Product in cans when exposed	Can size	Type of enamel* on ends	Disk† source and treatment	Days after exposure	Counts/ min	Days after exposure	Counts/ min
Sardines in oil	¼ drawn, unscored	San.	C +	32	56	68	34
			C −		74		43
			P +		59		36
			P −		67		42
Strained spinach	202 × 214	"C"	C +	21	148	61	98
			C −		96		50
			P +		102		75
			P −		54		30
Sardines in oil	¼ drawn, scored	San.	C +	28	61	68	36
			C −		53		26
			P +		47		35
			P −		65		37
Strained chicken soup	202 × 214	"C"	C +	21	140	62	82
			C −		82		42
			P +		81		50
			P −		37		16
Beets	303 × 406	San.	C +	27	34	64	22
			C −		32		22
			P +		92		54
			P −		84		44
Corn (whole kernel)	303 × 406	"C"	C +	26	269	64	205
			C −		85		63
			P +		203		154
			P −		30		21
Tomato soup (conc.)	211 × 400	"C"	C +	22	854	62	649
			C −		90		44
			P +		355		217
			P −		21		16
			Body		95		62
Beef stew	302 × 402	"C"	C +	26	246	64	202
			C −		51		29
			P +		378		299
			P −		106		63
Green beans	303 × 406	San.	C +	27	42	67	26
			C −		37		25
			P +		140		64
			P −		146		63
			Body		940		695
Consommé (conc.)	211 × 400	"C"	C +	21	442	61	308
			C −		22		13
			P +		728		538
			P −		97		45
			Body		420		304
Hamburgers	300 × 308	None	C	28	78	67	62
			P		132		76

Table 4.7—(Continued)

Product in cans when exposed	Can size	Type of enamel* on ends	Disk† source and treatment	Days after exposure	Counts/ min	Days after exposure	Counts/ min
Luncheon meat	12 oz (rec- tangular)	"C"	C +	32	468	68	346
			C –		54		30
			P +		458		340
			P –		56		37
			Body		96		69
Vegetable–beef soup (conc.)	211 × 400	"C"	C +	22	756	63	504
			C –		83		44
			P +		445		341
			P –		29		16
			Body		136		76
Corned beef hash	302 × 402	"C"	C +	32	373	68	294
			C –		41		20
			P +		511		422
			P –		81		45
Strained beef	202 × 214	San.	C +	22	46	62	26
			C –		43		19
			P +		76		51
			P –		72		40
Mushroom soup (conc.)	211 × 400	"C"	C +	21	64	61	44
			C –		15		14
			P +		163		85
			P –		84		44
			Body		82		47
Evaporated milk	14½ oz (snap end)	None	C	21	50	61	29
			P		118		63

* Enamels were not analyzed. Types of enamels are those generally used for the specific product involved. "C" designates a so-called "C enamel," which contains a zinc oxide pigment. San. designates all other clear type sanitary enamels.

† C, can-company's end. P, packer's end. +, inside surface enameled. –, enameled surface stripped with alcoholic KOH. Absence of + or – indicates unenameled surface. Bodies, where noted, were not enameled.

Product in jars when exposed	Enamel*	Days after exposure	Counts/ min	Days after exposure	Counts/ min	Base of empty jar after 208 hr
Chicken ravioli	+	27	91	67	57	1800
	—		76		50	
Strained spinach	+	21	158	61	112	2100
	—		85		47	
Strained carrots	+	21	190	61	113	
	—		96		44	
Pork and beans	+	32	128	68	87	1500
	—		66		40	
Beets	+	27	152	67	111	
	—		96		61	
Shrimp	+	26	381	63	322	4500
	—		79		48	
Frankfurters	+	32	128	68	82	3000
	—		72		43	
Fruits for salads	+					2100
Strained chicken soup	+	21	166	62	96	
	—		89		42	
Strained vegetables and lamb	+	22	144	62	104	
	—		86		46	
Strained beef	+	22	158	62	121	2700
	—		75		46	
Strained vegetables and liver	+	22	96	62	78	
	—		62		30	
Apple juice	+					3300
Strained vanilla custard	+	22	61	62	45	
	—		46		23	
Catsup	+					5400
Mixed vegetables (feeding test)	+	26	39	64	21	
	—		36		18	

* All enamels were of the sanitary type, as contrasted to "C" enamels, which contain zinc oxide pigments. +, readings taken on enameled surface. —, readings on similar surface after stripping enamel with alcoholic KOH.

months, were made on each disk with the same instrument that was used in determining the activities of the ashed samples. Planchets were not used in reading the metal disks. The disks were simply placed in the instrument, with the inner surface facing the Geiger tube.

Disks from which the enamel was to be removed were placed in a 20 per cent alcoholic solution of potassium hydroxide and warmed slightly for 1 or 2 min, after which the enamel was wiped from the surface with a clean cloth. To check the possibility of loss of the tin coating by solution in the alcoholic potassium hydroxide, a number of unenameled tin disks, having considerably larger surfaces than those used in determining the radioactivities, were subjected to the same stripping technique. These showed no detectable loss in weight.

Results. An examination of the results in Table 4.7 shows that with many containers there was a sharp reduction in the activity of the disks from which the enamel had been stripped. In the shrimp can, for example, the count at the can-company's end was reduced from 1313 to 112 c/m by removing the enamel. The greatest reduction in count occurs in the cans having "C" enamels. This type of enamel is used with sulfur-bearing food to prevent discoloration through the formation of iron sulfide. The sulfur released from the food product during

processing combines with the zinc oxide in the "C" type enamels, rather than with the iron from the container. In Sec. 4.1.2b, it was shown that a part of the induced radioactivity of many of the foods may be due to the formation of S^{35}. If this isotope were formed in any quantity in containers having "C" enamels, most of it should combine with the zinc in the enamel. This probably accounts, at least in part, for the fact that most of the cans having "C" type enamels showed considerable reductions in count on the disks stripped with alcoholic KOH.

In addition to this factor, cans having zinc-bearing enamels probably carried some Zn^{65} (half life 250 days) formed from Zn^{64} by neutron capture. This isotope may have contributed significantly to the activity of the "C" type enamels, and it would have been removed with the enamel by the alcoholic KOH treatment. Cans having sanitary type enamels showed only minor reductions in count after stripping. This type of enamel contains no zinc, and these minor reductions in count were probably due to the removal of small amounts of sulfide adhering to the enamel surface.

In cans with unenameled bodies most S^{35} would be expected to form a sulfide film on the unenameled portion of the containers. This has evidently happened in such cases as the mushroom soup, in which the ends had "C" enamel, and the green-bean can, in which the ends had sanitary enamel. In the latter case the body count was quite high, and the half life obtained from the two body counts approaches that of S^{35}. When disks taken from the unenameled bodies of radioactive cans were treated experimentally with alcoholic KOH, reductions in count were noted which were similar to those obtained with enameled cans. It was demonstrated that this treatment did not remove weighable quantities of tin, but it would dissolve a sulfide film, if present. It should be pointed out that enamels were not analyzed. The enamels indicated in Table 4.7 are those ordinarily recommended for the products involved. These samples were obtained from different sources, and the exact enamel type is not known in every case. Although it is not unusual for factories to substitute sanitary enamels for "C" types, especially when can inventories are low, it is believed that the sulfide and zinc explanation satisfactorily accounts for the reduction in count obtained on the treated disks.

The half lives obtained from the container data were too varied to be of much assistance in further identification of the active isotopes present. Most of these fell in the range of 40 to 90 days, but several of the cans with "C" enamel gave half lives in excess of 100 days. It is probable that in these cases a considerable portion of the activity is due to Zn^{65} (half life 250 days).

In Table 4.8, reductions in count are noted on disks cut from glass-jar closures and treated with alcoholic KOH. The enamels here were all of the sanitary type, containing no appreciable amount of zinc. The reductions in counts obtained may be ascribed to the removal of a sulfide film by the alcoholic KOH.

Readings taken at the base of empty glass jars 208 hr after their exposure are given in the last column of Table 4.8. These readings were made with the Anton radioactivity comparator (see Sec. 3.2) on similar containers exposed at 1270 ft and are included to indicate the residual activity of the jars about nine days after their exposure. Early readings on the jars showed that the glass containers had a very high initial activity due to the formation of Na^{24} from the common isotope of sodium, a constituent of most glasses. Because this isotope of sodium has a half life of only 15 hr, the initial activity declined rapidly, e.g., to $\frac{1}{16}$ in 60 hr, $\frac{1}{64}$ in 120 hr, etc.

A comparison of the container activities in Tables 4.7 and 4.8 with those of the products in Table 4.3 shows no relation between the induced activities of containers and contents. This was especially true of earlier readings taken shortly after the explosion but not tabulated in this report. *Container radioactivity has no bearing on the suitability of the food for use. Thus, if a container shows considerable activity when monitored after an explosion, it should not be discarded on that basis alone. Very active containers in many instances will contain food that is entirely safe.*

(d) Taste Tests for Acceptability. Sixty-three products exposed at 1270 ft from Ground Zero to maximum radiation effects (see introductory remarks for this chapter) were compared with unexposed controls in triangular taste tests to determine difference and preference (Table 4.9). All the products showed induced radioactivity immediately after the shot (see Table 4.3).

Table 4.9 — TRIANGULAR TASTE TESTS ON NUCLEAR TEST SAMPLES

| Product | Container | Results of 30 judgments | | | | |
		No. correct judgments	Signifi- cance	No. correct judgments expressing preference	No. pre- ferring control	No. pre- ferring exposed
Corn (whole kernel)	303 × 406	10	None	3	1	2
Peas	303 × 406	7	None	6	5	1
Green beans	303 × 406	9	None	7	2	5
Beets	303 × 406	11	None	5	3	2
Beets	16-oz jar	12	None	6	1	5
Sauerkraut	401 × 411	13	None	3	1	2
Sweet potatoes	404 × 307	10	None	5	3	2
Peaches	401 × 411	10	None	6	4	2
Pineapple	401 × 411	14	None	5	1	4
Pears	401 × 411	12	None	4	2	2
Applesauce	303 × 406	11	None	6	1	5
Grapefruit	303 × 406	14	None	7	4	3
Blueberries	300 × 407	14	None	7	2	5
Blackberries	303 × 406	9	None	4	0	4
Purple plums	401 × 411	19	0.1% level	10	3	7
R.S.P. cherries	603 × 700	13	None	7	2	5
Fruits for salad	28-oz jar	12	None	7	4	3
Tomato juice	404 × 700	10	None	5	3	2
Orange juice	404 × 700	12	None	9	7	2
Pineapple juice	404 × 700	15	None	10	3	7
Apple juice	32-oz bottle	25	0.1% level	17	16	1
Grape juice	12-oz bottle	14	None	5	3	2
Salmon	301 × 411	9	None	5	3	2
Tuna	307 × 113	12	None	7	5	2
Sardines in oil	¼ drawn, scored	11	None	4	0	4
Sardines in oil	¼ drawn, unscored	6	None	2	0	2
Sardines in tomato sauce	1 lb (oval)	12	None	3	1	2
Shrimp	211 × 300	13	None	6	4	2
Shrimp	6-oz jar	10	None	4	1	3
Luncheon meat	12 oz (rec- tangular)	7	None	2	1	1
Hamburgers	300 × 308	9	None	4	2	2
Frankfurters	300 × 407	7	None	1	0	1
Frankfurters	8-oz jar	6	None	4	1	3
Chicken	300 × 108	10	None	3	3	0
Pork and beans	300 × 407	11	None	5	5	0
Pork and beans	16-oz jar	18	1% level	7	4	3
Beef stew	302 × 402	12	None	7	3	4
Spaghetti	300 × 407	10	None	5	2	3
Corned beef hash	302 × 402	15	None	7	5	2
Catsup	14-oz bottle	17	1% level	11	4	7
Ravioli	14-oz jar	6	None	0	0	0

Table 4.9 — (Continued)

| Product | Container | Results of 30 judgments | | | | |
		No. correct judgments	Signifi- cance	No. correct judgments expressing preference	No. pre- ferring control	No. pre- ferring exposed
Tomato soup (conc.)	211 × 400	8	None	4	3	1
Vegetable-beef soup (conc.)	211 × 400	7	None	3	1	2
Mushroom soup (conc.)	211 × 400	11	None	4	3	1
Mushroom soup (ready to serve)	211 × 414	11	None	4	1	3
Consommé (conc.)	211 × 400	7	None	4	1	3
Strained spinach	202 × 214	17	1% level	11	3	8
Strained spinach	5-oz jar	13	None	8	3	5
Strained carrots	202 × 214	11	None	5	3	2
Strained carrots	5-oz jar	7	None	3	1	2
Strained apricots and apples	202 × 214	8	None	2	2	0
Strained apricots and apples	5-oz jar	11	None	9	2	7
Strained bananas	202 × 214	9	None	3	0	3
Strained bananas	5-oz jar	14	None	7	5	2
Strained chicken soup	202 × 214	6	None	1	0	1
Strained chicken soup	5-oz jar	9	None	2	1	1
Strained vegetables and lamb	202 × 214	12	None	5	2	3
Strained vegetables and liver	202 × 214	7	None	5	4	1
Strained vegetables and liver	5-oz jar	16	5% level	10	5	5
Strained vanilla custard	202 × 214	11	None	5	4	1
Strained vanilla custard	5-oz jar	16	5% level	7	3	4
Strained beef	3½-oz jar	15	None	6	3	3
Evaporated milk	14½ oz (snap end)	9	None	4	3	1

However, only one or two of the products were detectably above background when the taste tests were begun six months after the shot. The entries in columns 3 through 7 of Table 4.9 refer to the number of testers, out of 30, who were able to detect the different sample from the set of three, in which two were identical. The evaluation of significance is based on a table from reference 4 which shows that at least 16 correct differentiations out of 30 are required before significance can be attributed at the 5 per cent level.

In only seven instances was there a significant selection of the "different sample." One was a fruit, purple plums; one a fruit juice, apple juice; two were specialties, pork and beans and catsup; and three were in the baby-food category, strained spinach, strained liver and vegetables, and strained vanilla custard. In a single instance there was a significant prefer- ence expressed for the control. This was with apple juice, in which instance 16 of 17 correct judgments expressing preference preferred the control on the basis of sweetness. None con- sidered the exposed juice objectionable.

All the products tested had been exposed under deliberately exaggerated conditions and were found acceptable. In view of this, it may be concluded that any canned foods surviving a nuclear explosion would be satisfactory from a flavor and texture standpoint.

4.1.3 Emergency Aboveground Shelters

Of the several types of aboveground outdoor family shelters under test, canned foods were exposed in one at 2250 ft and in one at 3750 ft from Ground Zero (Table 2.3). These shelters are utility or tool sheds 6 ft square and 7 ft high on the inside, with walls 8 in. thick. Figure 4.8 shows cased foods in the masonry block shelter at 3750 ft. Comparable samples were on wooden shelves against the wall of a concrete shelter at 2250 ft.

Figure 4.9 shows the demolished shelter at 2250 ft with a roof section supported by cases of the canned foods. This shelter was moved bodily about 30 ft. Some cases were pinned in the wreckage and could not be recovered, and others were blown apart and their contents strewn for up to 150 ft. Most of the container failure was due to flying missiles, such as stones (Fig. 4.10), and to crushing. In spite of this destruction and the fact that personnel in this shelter would not have survived, either because of crushing or of lethal doses of radiation, 67 per cent of the 491 containers located here as part of Test 1 were recovered in usable condition.

The masonry block shelter at 3750 ft was intact following the blast, although the inner door was blown from its hinges and fell against the far wall. The unopened containers exposed here and scaled comparatively with the Anton instrument were not detectably above background at 80 hr after the shot (H+80 hr). Unopened containers of products known to be most subject to induced activity were recovered from the shelter located at 2250 ft and were scaled comparatively with the Anton instrument at H+80 hr. Shrimp in tin and glass containers gave 2250 to 4500 c/m above background; whereas tuna in tin gave 900 c/m and sardines in tin gave 150 to 600 c/m above background. These results are considered insignificant when considered in terms of the results of more quantitative scaling of the samples at 1270 ft (see Sec. 4.1.2b).

4.1.4 Residential and Industrial Structures

It will be noted in Table 2.3 that exposures of canned foods were made in duplicate structures at two distances from Ground Zero. These included one-story precast concrete houses at 4700 and 10,500 ft; two-story white frame houses at 5500 and 7800 ft; and corrugated metal self-framing industrial buildings at 6800 and 15,000 ft.

None of the products exposed in these structures suffered damage from radiation. In general, depending on distance and location, there was some dislodgment from shelves, and in a few instances there was container perforation or breakage due to flying missiles. In this respect, basement storage was definitely preferable to kitchen storage.

(a) Precast Concrete Houses. Figure 4.11 shows the exterior of the precast concrete house at 4700 ft after the blast. Figure 4.12 shows a general postshot view of the kitchen area. Structural damage to this house was considered minor, and the canned foods on the kitchen shelves were relatively undisturbed. The shelves were on the kitchen wall parallel to the direction of the blast. The left section doors were found open after the blast, and the entire cabinet had been shifted along the wall about $1\frac{1}{2}$ in. (Fig. 4.13). Only 6 of the 396 containers were thrown to the floor, 2 of these being jars, which broke as a result of the fall.

At 10,500 ft from Ground Zero the cabinet doors remained closed, and there was no damage to the canned foods.

(b) Two-story White Frame Houses. Canned foods were exposed in the kitchens and basements of two identical white frame houses located at 5500 and 7800 ft from Ground Zero (Table 2.3). The house at 5500 ft suffered severe damage (Fig. 4.14), and the one at 7800 ft suffered relatively heavy damage. Figures 4.15 and 4.16 show the kitchen exposures at 5500 ft before and after the shot. The cabinets were along the forward wall with their long axis at right angles to the force of the blast. The drumhead action forced the shelves about 2 to 3 in. away from the wall, and 296 of the 408 containers were thrown to the floor. Sixteen of the jars so dislodged were broken, and there was some denting of the tin containers. There was no other damage and no induced radioactivity. At 7800 ft the blast results in the kitchen were essentially the same, although all the cabinet doors remained on their hinges. Figure 4.17 shows how 260 of the 414 containers were thrown to the floor.
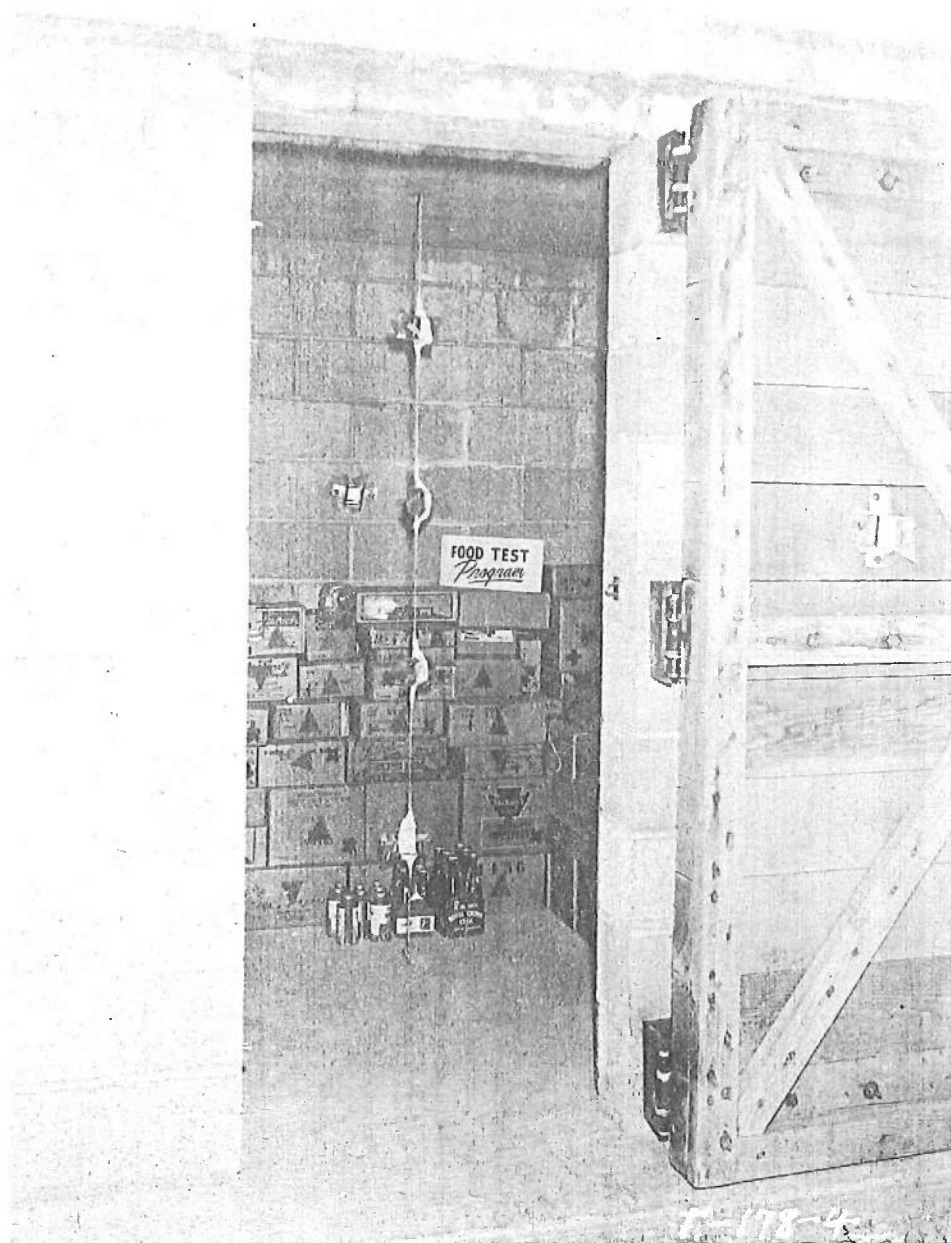
Fig. 4.8—Samples located on floor of masonry block utility type shelter at 3750 ft from Ground Zero.
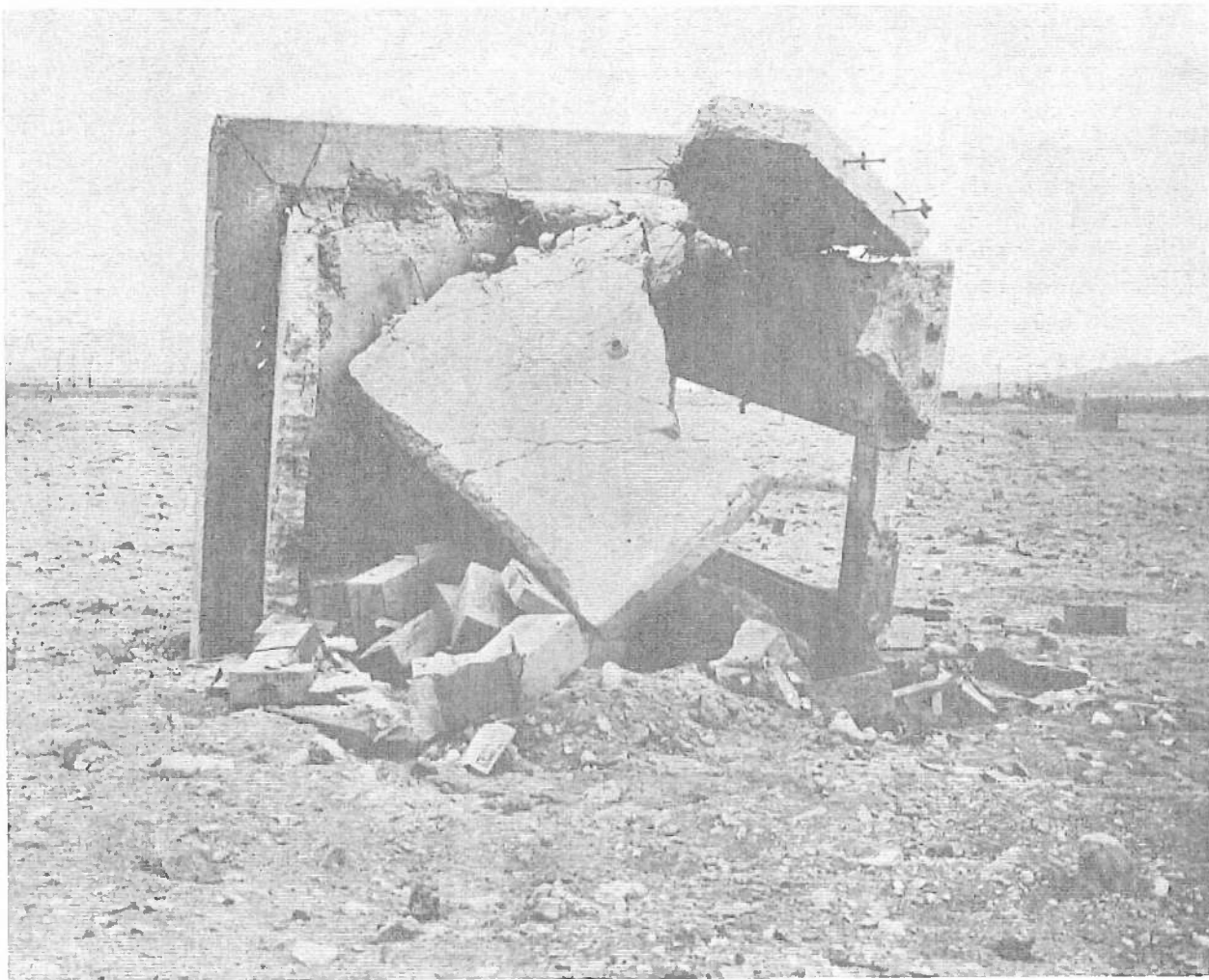
Fig. 4.9 — Demolished concrete utility type shelter at 2250 ft from Ground Zero, showing tumbled cases of canned foods. Sixty-seven per cent of samples were recovered in usable condition.
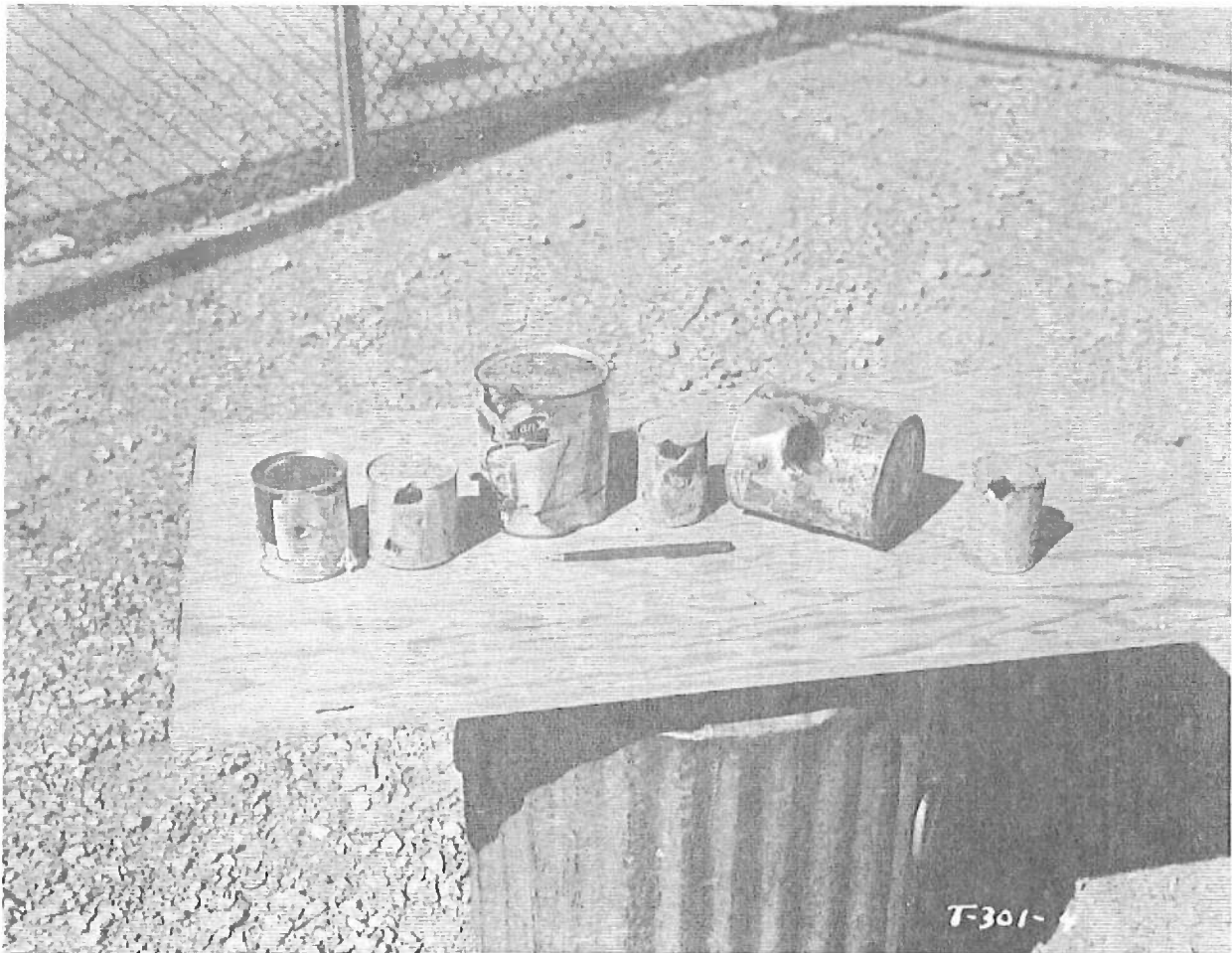
Fig. 4.10 — Some extreme samples of damage from flying missiles. These cans were recovered from the shelter at 2250 ft from Ground Zero. Note the stone still in position at the top of the third can from the left. Of the samples at this exposure, some 67 per cent were recovered in usable condition.
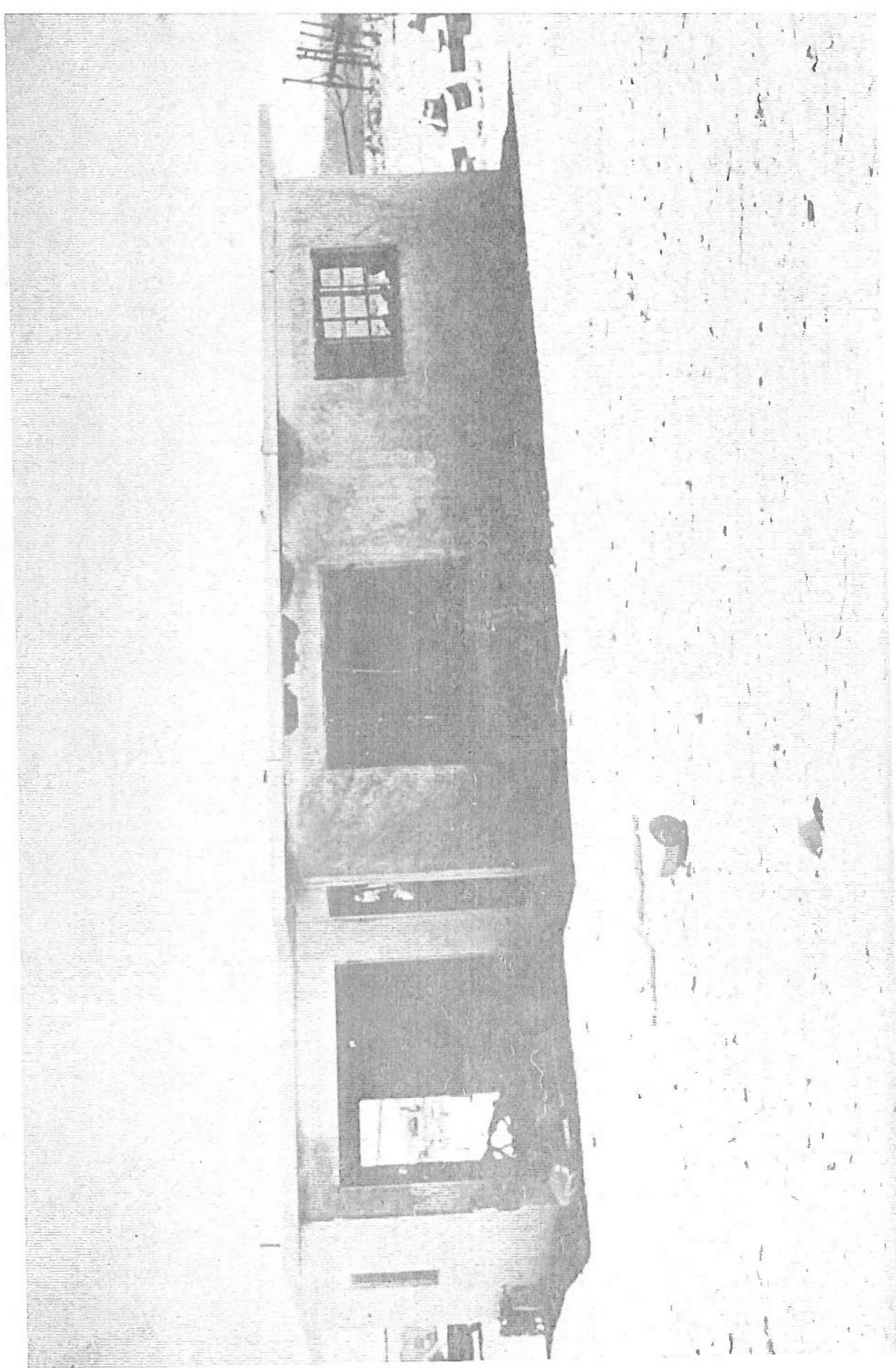
Fig. 4.11 —Exterior view of precast concrete house at 4700 ft from Ground Zero after blast.
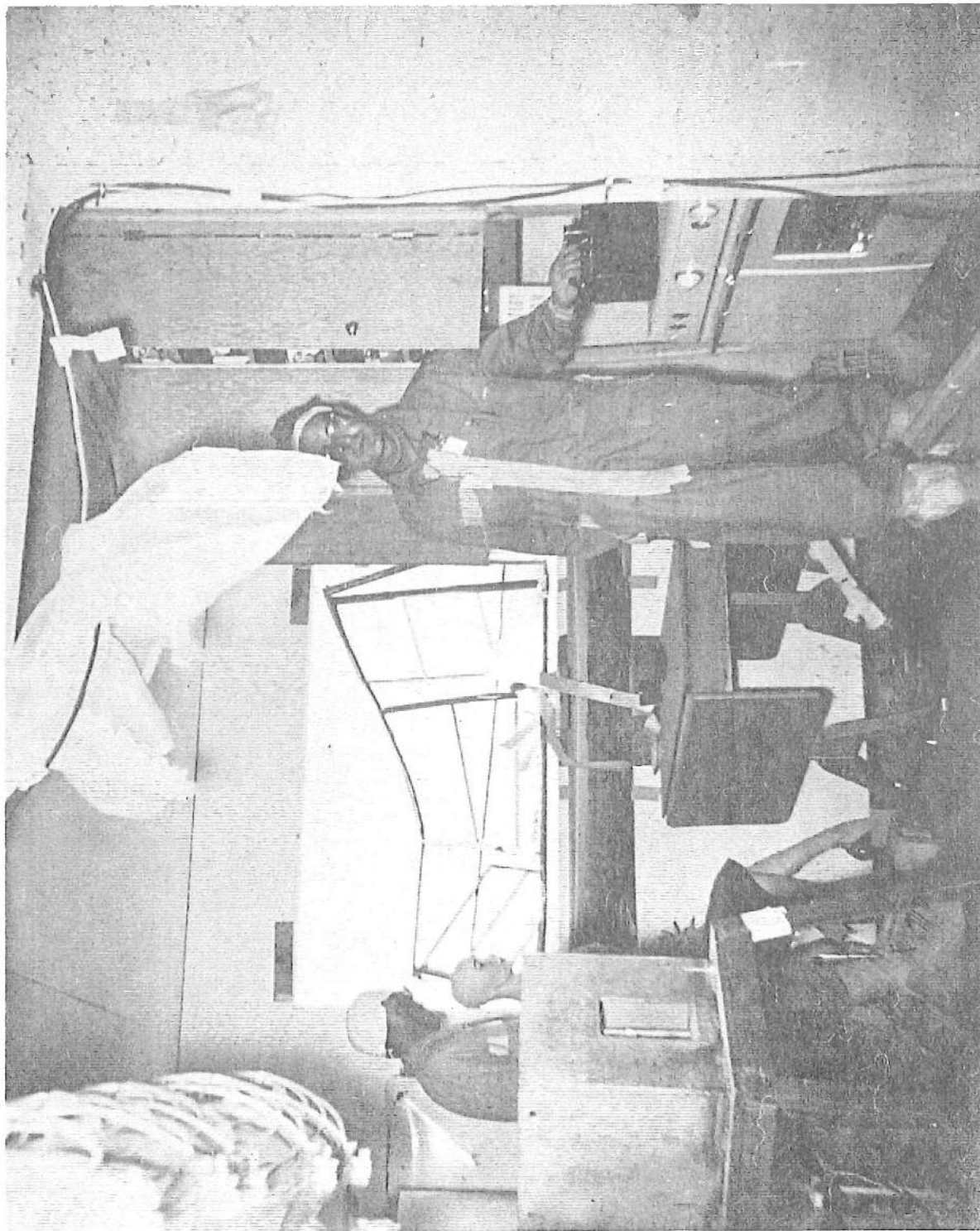
Fig. 4.12 — Postshot view of kitchen area in precast concrete house at 4700 ft from Ground Zero.

Fig. 4.13—Postshot view of kitchen shelves in precast concrete house at 4700 ft from Ground Zero.

Fig. 4.14—Postshot view of white frame house at 5500 ft from Ground Zero.

Fig. 4.15—Kitchen cabinets of white frame house at 5500 ft from Ground Zero before the shot.

Fig. 4.16 — Kitchen cabinets of white frame house at 5500 ft from Ground Zero after the shot.
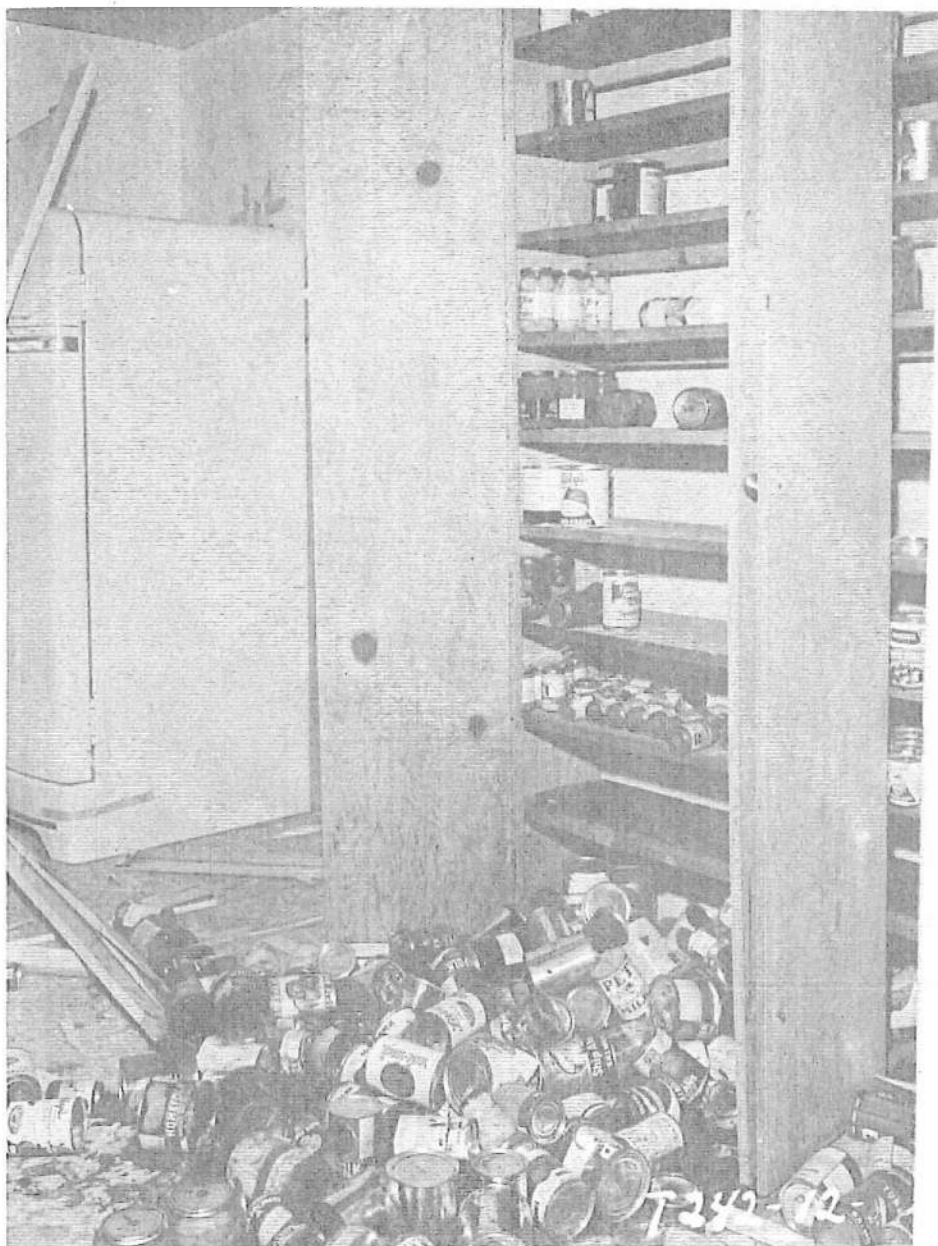
Fig. 4.17—Kitchen cabinets of white frame house at 7800 ft from Ground Zero after the shot.

Containers exposed in the basements were on open shelves along the back wall at 5500 ft (Fig. 4.18) and along the front wall at 7800 ft. Although there was substantial damage to ceiling joists at 5500 ft (Fig. 4.19), none of the containers were dislodged from the shelves. The end of the shelves shown in Fig. 4.19 was in open line with a front basement window and was showered with flying fragments of window glass. Two tin cans were punctured by these fragments. The shelves at 7800 ft were not in line with a window, and none of the containers were dislodged or punctured (Fig. 4.20).

The results indicate that basement storage is preferable for emergency food supplies and that the storage area should be out of direct line with windows or door glass.

(c) *Self-framing Corrugated-metal Industrial Buildings.* Both cased and uncased tin and glass containers were exposed along the rear walls of two identical buildings at 6800 and 15,000 ft from Ground Zero (Table 2.3). The aim was to simulate storage conditions that might prevail in a retail outlet of the supermarket type. The building at 6800 ft was severely damaged but remained bolted together. The two front windows and the door were blown inward, showering the food shelves with flying glass. Sections of the door frame were blown against the lower left shelves, causing some damage (Fig. 4.21). Of the 656 containers exposed uncased on these shelves, 13 cans were punctured by the window-glass missiles, 1 can was ruptured by a door fragment, and 16 jars were broken by missiles or dislodgment from the shelves. There was no damage to the cased samples.

At 15,000 ft some glass and wood fragments were found on the shelves (Fig. 4.22), but there was no major structural damage. Only 15 of 662 canned-food containers were knocked to the floor, only 1 jar being broken as a result of the fall.

4.1.5 Cases Exposed Unprotected on Ground Surface

(a) *Pallet Load.* It was felt that, under conditions of atomic warfare, warehouses containing palletized loads of canned food might be subjected to severe blast and intense radiation and that under these conditions the front cases in pallet loads might shield the rear cases from any adverse effects. To test this hypothesis, a typical pallet load was exposed on the ground surface at 1 mile from an approximately nominal shot. In that instance the load was strapped to the pallet with five bands of $\frac{5}{8}$-in. metal strapping. Charring of case faces toward Ground Zero occurred, and cases in the load were spread apart against the strapping, leaving about $\frac{1}{2}$-in. space between cases. None of the cans or jars in the load were damaged.

For the open shot the pallet load was rebuilt, but was not strapped, and was located at 4700 ft from Ground Zero (Fig. 2.11). Blast overpressures at this distance resulted in major damage to structures and disrupted the pallet load. Only 4 of the 40 cases remained on the pallet (Fig. 4.23). One case of No. 10 cans was blown 40 ft, and loose cans were recovered as far away as 60 ft. Thirty of the forty cases remained intact. All containers were recovered with contents intact, although some denting occurred as a result of the tumbling.

Results of gamma-radiation dosimetry in both tests indicated that rear cases in the load received only $\frac{1}{5}$ to $\frac{1}{2}$ the gamma dose received by the front cases. This has no direct significance in view of acceptability tests reported in Sec. 4.1.2d but serves to illustrate what might be significant self-shielding under some circumstances.

(b) *Individual Case Exposures.* As part of the general test (as well as of Test 2 on container damage and spoilage and Test 4 on nutritive factors), individual cases were exposed on the desert floor without structural protection at 5500 ft from Ground Zero (Fig. 2.10). Some of these cases were tumbled a distance of 5 to 15 ft (Fig. 4.24), and case faces toward the blast were scorched or charred to various degrees (Fig. 4.25). Duplicate cases on the ground surface at 7800 ft were not disturbed or scorched. The products at both distances were normal in all respects.

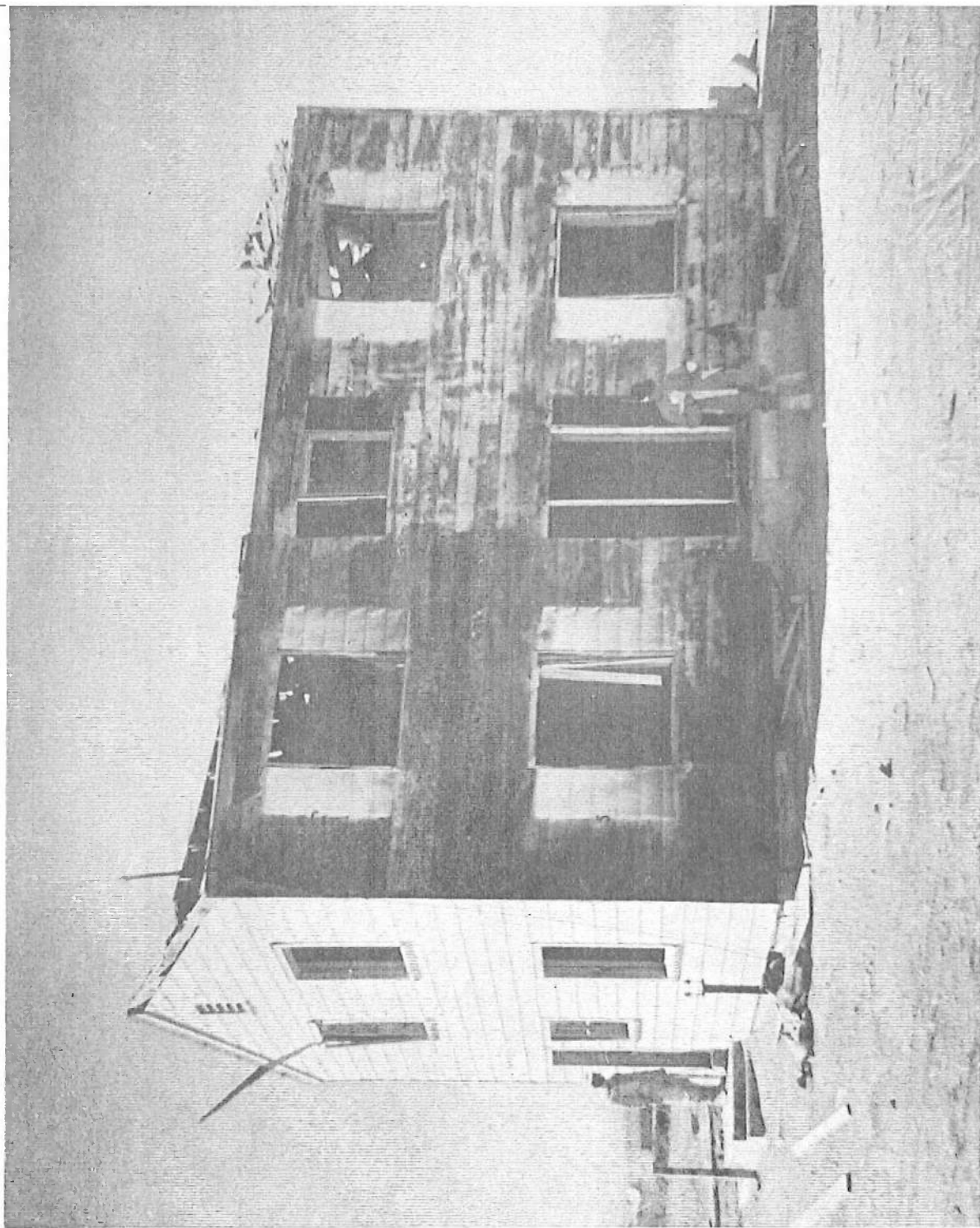Fig. 4.18—Cased and uncased foods on basement shelves of white frame house at 5500 ft from Ground Zero before the shot.

Fig. 4.19—Postshot view of basement of white frame house at 5500 ft from Ground Zero.

Fig. 4.20 — Postshot view of basement shelves in white frame house at 7800 ft from Ground Zero.
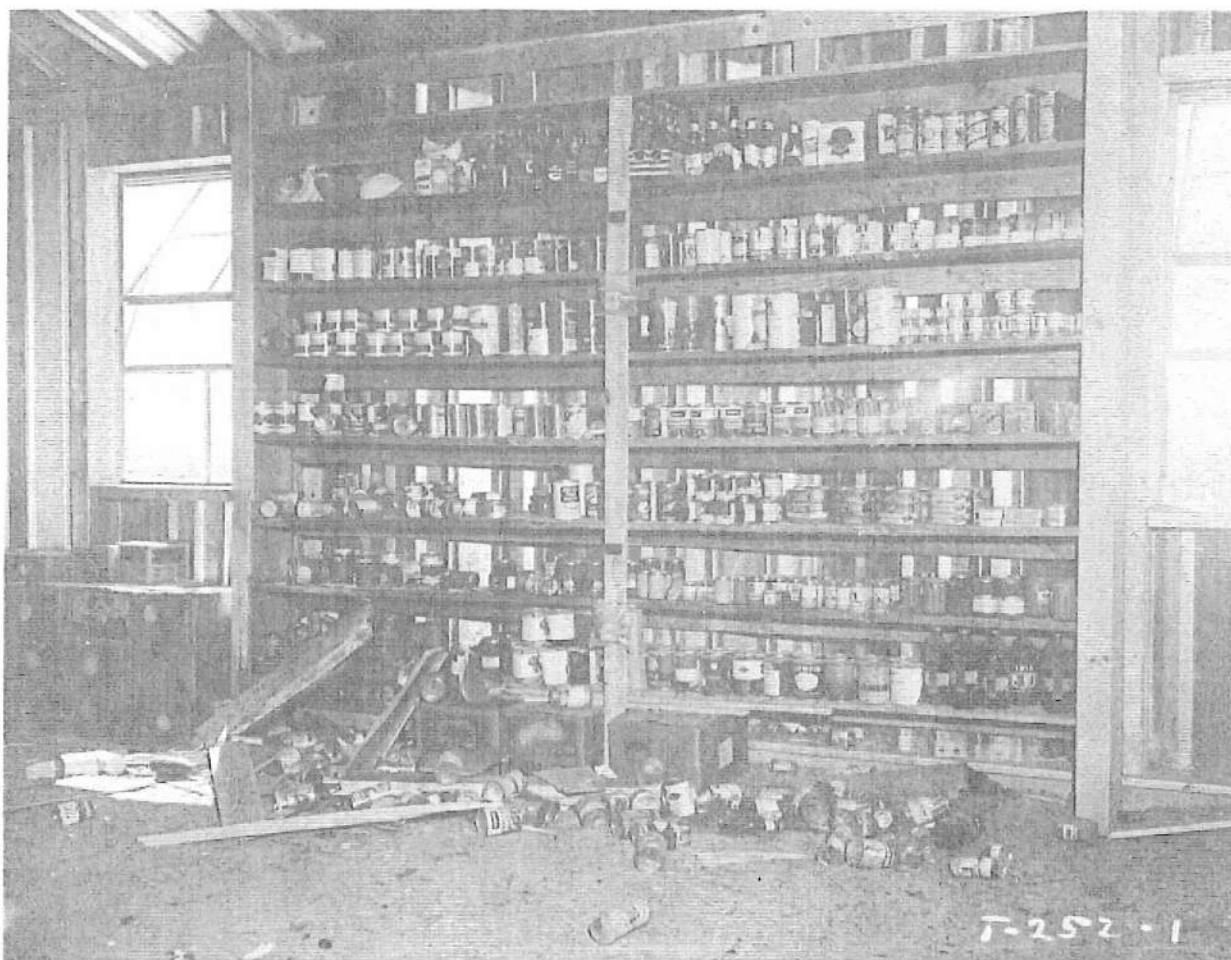
Fig. 4.21 — General view of uncased samples on shelves in industrial building of corrugated
sheet metal 6800 ft from Ground Zero, following the blast. (Note door fragments at lower left.)

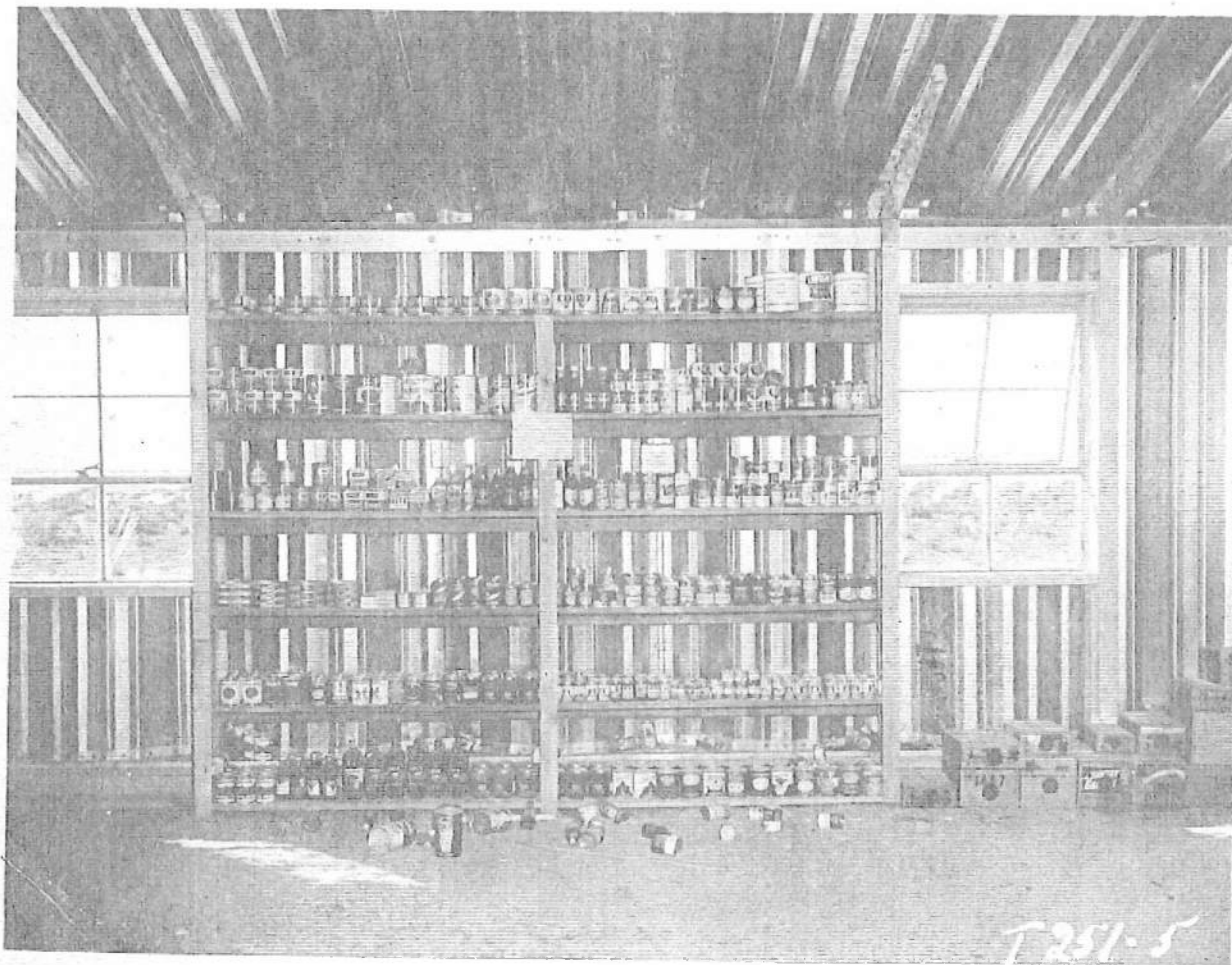Fig. 4.22—Postshot view of food shelves in industrial building of corrugated sheet metal 15,000 ft from Ground Zero.

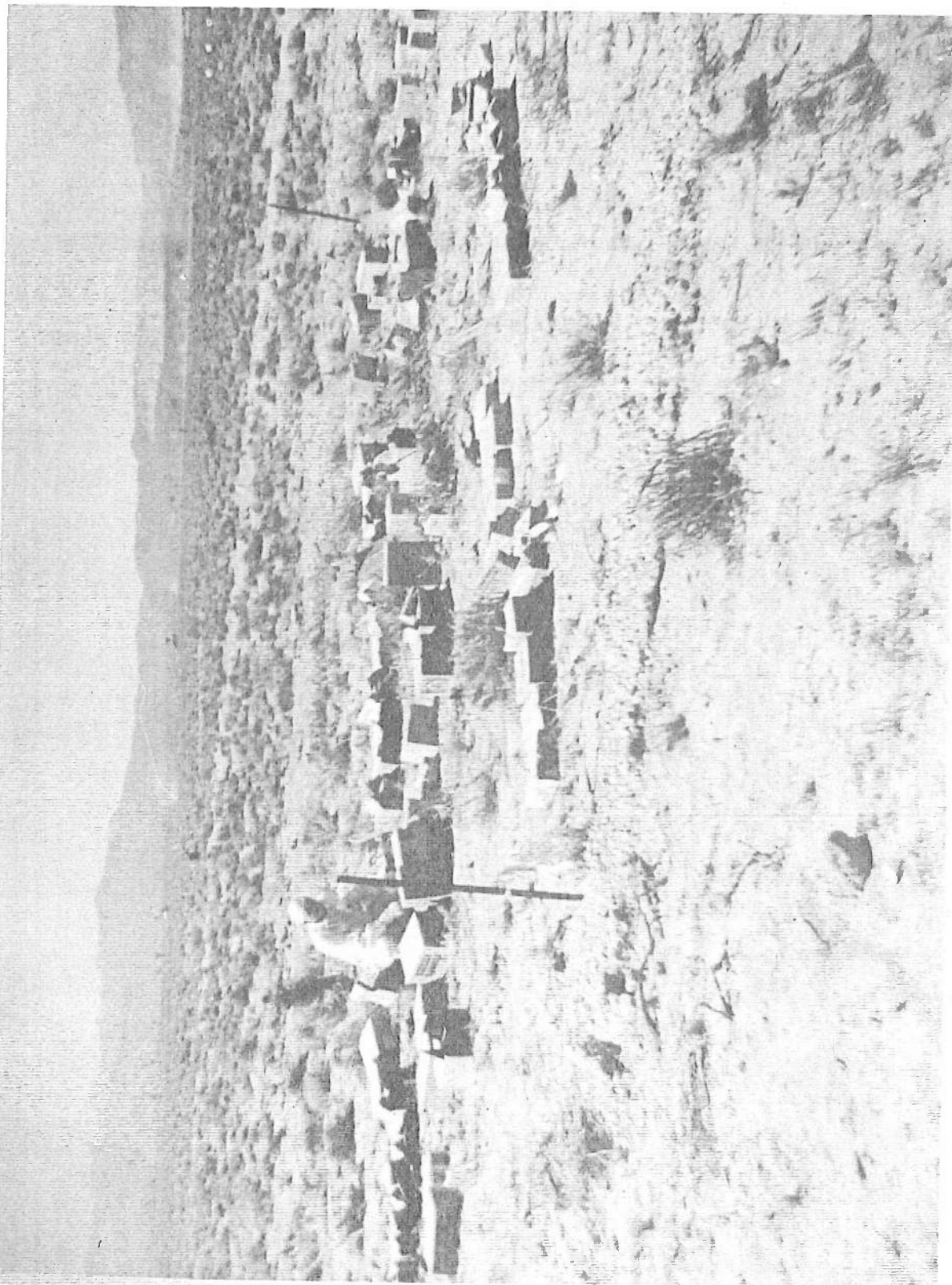Fig. 4.23—Pallet load scattered on the ground surface at 4700 ft from Ground Zero, following the blast.

Fig. 4.24 — Postshot view of cases exposed on the ground surface at 5500 ft from Ground Zero.
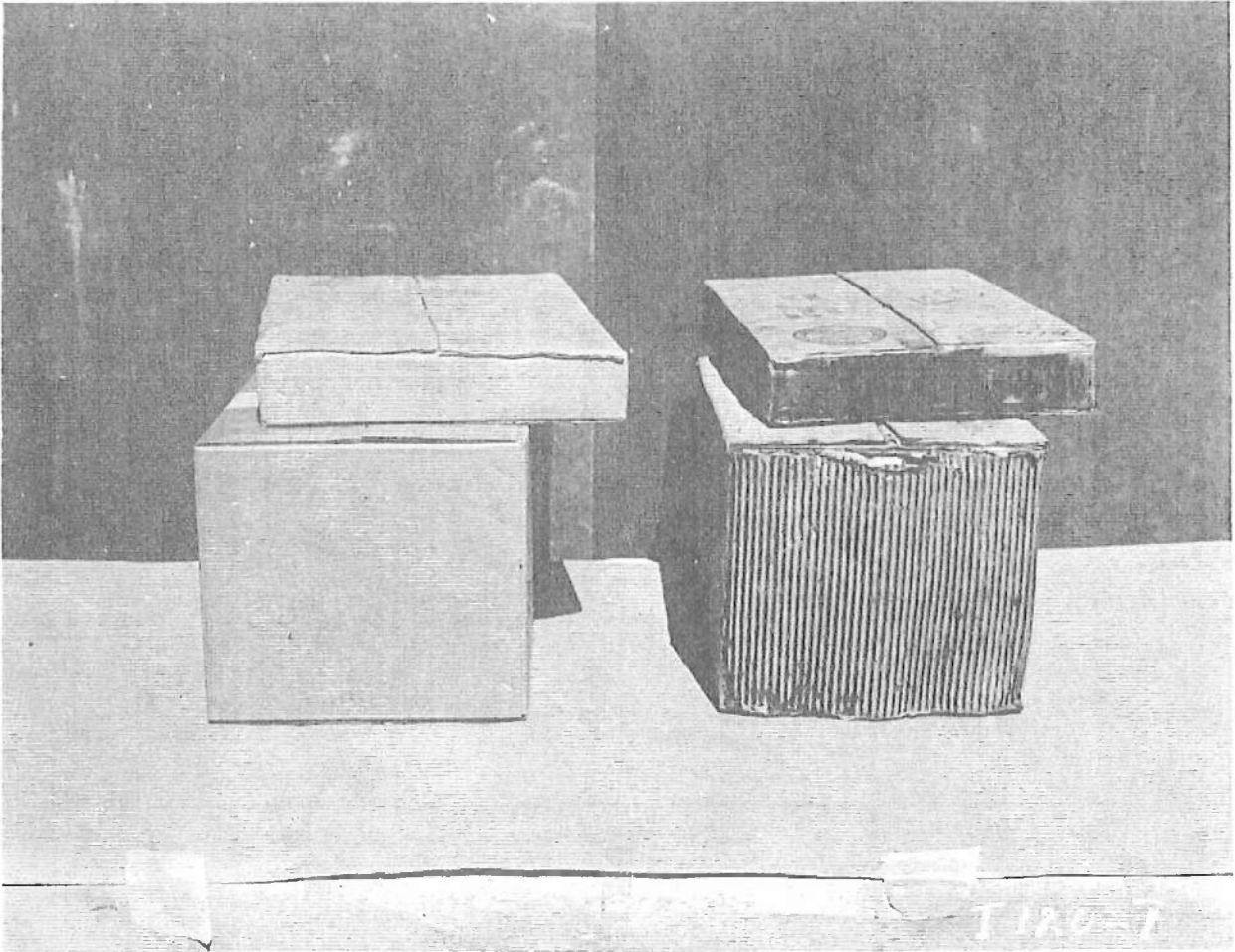
Fig. 4.25—Control cases (left) and scorched cases (right) from 5500-ft ground-surface exposure.

4.2 TEST 2: SPECIAL INCUBATION TEST ON INFLUENCE OF INTERNAL VACUUM AND CONTAINER SIZE UPON CONTAINER DAMAGE AND SPOILAGE

As described in Sec. 2.3, all samples for Test 2 were in cases deliberately inoculated with organisms to enhance spoilage potentialities if the hermetic seal of the tin or glass containers were momentarily broken owing to the positive and negative pressure phases of the nuclear-device explosion. It was hypothesized that spoilage organisms might enter the container as a result and make the food unfit for use. Since container size, internal vacuum, type of food, or type of jar closure might be involved, these variables were included.

4.2.1 Exposure Conditions and Sample Quantity

Table 4.10 shows the number of samples recovered from each exposure condition. Breakage or crushing losses were encountered only at the first two exposures listed; 95 per cent of the samples at 1270 ft and 55 per cent of those at 2250 ft were recovered intact.

Table 4.10 — NUMBER OF SAMPLES RECOVERED AT EACH
EXPOSURE CONDITION

Exposure condition	Distance from Ground Zero, ft	No. of units recovered	
		Tin	Glass
Buried with 2 to 3 in. of earth cover	1,270	34 cases	9 cases
Concrete utility shelter	2,250	307 cans	71 jars
Masonry block utility shelter	3,750	15 cases	10 cases
Basement of two-story white frame house	5,500	34 cases	10 cases
Ground surface	5,500	35 cases	11 cases
Corrugated-metal industrial building	6,800	20 cases	10 cases
Basement of two-story white frame house	7,800	16 cases	4 cases
Ground surface	7,800	16 cases	4 cases
Corrugated-metal industrial building	15,000	16 cases	4 cases
Total		3,391 cans	1,379 jars

4.2.2 Nature of Samples

Table 2.2 lists the products and container sizes used in this test. Commercially packed products in tin were selected to represent high (18 + in.), medium (10 to 15 in.), and low (3 to 7 in.) packing vacuums. Since glass-packed products are all packed under high vacuum, the three major cap styles commercially used were included as an alternative variable in the special packs of nutrient medium. The nutrient packing medium used for the special samples and the packing vacuums are described in Sec. 2.1.

4.2.3 Procedures After Exposure

All recovered samples were shipped by trailer to the Berkeley, Calif., laboratory of the National Canners Association. Storage was at room temperature, and periodic examinations were made for swelled cans or jars with blown caps. After seven months' storage the samples were checked for actual vacuum, acidity of contents (pH), and product appearance. Bacteriological examination was made on all abnormal products to determine the type of spoilage organism. In addition, detailed container examinations were made to assist in determining the cause of spoilage.

4.2.4 Results and Discussion

No spoilage was encountered in samples exposed at a distance of 7800 ft or greater from Ground Zero. Spoilage encountered at closer distances (6800 ft or less) is given in Table 4.11. The seven spoiled cans listed in Table 4.11 represent 0.28 per cent of the 2522 commercially packed cans exposed, or a spoilage rate of three cans per thousand. Of these seven cans; three were obviously damaged, leaving only four (1.6 cans per thousand) of undetermined cause. The seven spoiled cans listed in Table 4.12 represent 0.8 per cent of the 869 cans of nutrient medium exposed (8 cans per thousand).

Table 4.11—COMMERCIALLY PACKED FOODS IN TIN CONTAINERS

Product	Can size	Distance from Ground Zero, ft	Appearance of spoiled can	Condition of spoiled contents	Can defect
Pumpkin	401 × 411	1270	Swelled	Sour and gassy	Fractured plate at dent on double seam
Tomato juice	404 × 700	1270	Flat (no vacuum)	Sour	None apparent
Spinach	603 × 700	1270	Flat (no vacuum)	Sour	Fractured plate at dent on body
Pumpkin	401 × 411	2250	Swelled	Sour and gassy	None apparent
Pumpkin	401 × 411	2250	Flipper	Sour and gassy	None apparent
Tomato juice	404 × 700	6800	Swelled	Sour and gassy	None apparent
Junior chicken soup	211 × 210	6800	Swelled	Sour and gassy	Perforated body plate

Table 4.12—SPECIALLY PACKED NUTRIENT MEDIUM IN TIN CONTAINERS

Container size	Distance from Ground Zero, ft	Approx. original vacuum, in.	Final vacuum, in.
307 × 409 can	1270	5	0
401 × 411 can	1270	5	Can flat
401 × 411 can	3750	5	0
307 × 409 can	5500*	20+	4
307 × 409 can	5500*	12 to 14	0
401 × 411 can	5500*	5	4
307 × 409 can	6800	5	Pressure (swelled)

* At ground surface.

Organisms recovered from spoiled cans, or observed on direct microscopic examination, consisted of yeasts and mixed bacterial cultures of low resistance to heat. These were the same types of organisms used to inoculate the cases and are also the types found in ordinary spoilage due to leakage. In a number of instances viable organisms could not be recovered because they had died out during the storage period (autosterilization). However, spoilage of products was easily detectable by appearance or taste.

Spoilage rates of about two cans per thousand (as shown by the commercially packed cans) are not unknown in the industry, especially when adverse handling conditions such as those en-

countered in these tests are experienced. The rate of eight cans per thousand in cans of nutrient medium and the absence of direct correlation with exposure distance (positive and negative blast pressures) led to detailed examination of the double-seam formation on these specially packed cans. This revealed that the top double seams were badly defective owing to maladjustment of the closing machine used, and it appears that the high incidence of spoilage was due to this condition rather than to a direct effect of the blast pressures. The low spoilage incidence on the commercial packs supports this conclusion.

Of the total of 1379 jars exposed in inoculated cases only two were abnormal in any respect; these are given in Table 4.13. Because of their slightly low pH the jar contents were examined microscopically and bacteriologically. No organisms were observed on direct smear, and none could be recovered on culturing. In view of this it is felt that the slightly low pH was not due to spoilage.

Table 4.13—ABNORMAL pH OF JARS OF FOOD EXPOSED IN INOCULATED CASES

Container size	Distance from Ground Zero, ft	Contents	pH Original	Final	Vacuum, in. Av. original	Final
8-oz jar	2250	Chicken soup	6.3	5.8	22	8
8-oz jar	5500 (ground surface)	Nutrient medium	6.3	5.9	22	22

The results on commercial packs in tin and commercial packs and special packs in glass indicate that the pressure conditions resulting from a nuclear explosion (up to a maximum of about 45 psi overpressure) do not cause either momentary or permanent nonevident loosening of the can seams or jar closures.

4.3 TEST 3: SPECIAL TEST ON REMOVAL OF FALL-OUT CONTAMINATION

Open cases of small, intermediate, and large sizes of tin and glass containers were exposed at $4\frac{3}{4}$ and 7 miles from Ground Zero in an approximately nominal shot in an attempt to obtain fall-out contamination, without success. In the open shot similar exposures were made in one location at 2 miles and in three locations at 15 miles from Ground Zero, again without success. Some fall-out was obtained on other packaging materials which indicated that porous, rough, or greasy surfaces would be difficult to decontaminate. Smooth surfaces appeared to trap less fall-out material and seemed easier to decontaminate by wiping, brushing, or washing.

4.4 TEST 4: SPECIAL TEST ON RETENTION OF ESSENTIAL NUTRITIVE FACTORS

Considerable information is available about the effects of beta and gamma types of radiations on vitamin content and shows that there is a great variation in radiation tolerance of the specific vitamins in different natural foods, depending on the total dose received. The aim of this test was to determine the effect of radiations produced by the nuclear device upon carotene, ascorbic acid, thiamine, riboflavin, and niacin.

4.4.1 Procedures

The products selected for exposure and the vitamins of chief concern in each are given in Sec. 2.1. Table 2.2 shows the can sizes used. Exposures were made at three distances from Ground Zero, namely 1270, 5500, and 7800 ft, as described in Sec. 2.3.4.

The samples of each canned food were obtained from a single commercial packer, and all food comprising the sample was canned on the same day. Control cans were handled in the

same manner as cans to be exposed except during the actual exposure period, when they were stored in a metal shed at the test site. After the shot six control cans and six cans of each food exposed to maximum radiation at 1270 ft from Ground Zero were shipped to the Wisconsin Alumni Research Foundation for assay. The vitamin assays were made on a composite sample of the six cans by the recognized methods discussed in the following references.

Vitamin	Reference
Ascorbic acid	W. B. Robinson and E. Stotz, The Indophenol-Xylene Extraction Method for Ascorbic Acid and Modifications for Interfering Substances, J. Biol. Chem., 160: 217 (1945).
β-carotene	Official Methods of Analysis of the Association of Official Agricultural Chemists, 7th ed., p. 769, 1950.
Niacin	Pharmacopoeia of the United States, Rev. XIV, p. 737, U. S. Pharmacopoeial Convention, 1950.
Riboflavin	Pharmacopoeia of the United States, Rev. XIV, p. 752, U. S. Pharmacopoeial Convention, 1950.
Thiamine	Pharmacopoeia of the United States, Rev. XIV, p. 771, U. S. Pharmacopoeial Convention, 1950.

Since no significant losses were encountered in the samples at 1270 ft, assays were not made on the samples exposed at greater distances.

4.4.2   Results and Discussion

Table 4.14 lists the results of assays for reduced ascorbic acid, niacin, riboflavin, thiamine, and carotene. The vitamin content, expressed in milligrams per 100 grams, is given for both the exposed and the control samples; the per cent retained, based on the content of the control samples, has also been given. For purposes of comparison, average, maximum, and minimum values for similar commercially produced products have also been included. These figures were obtained from reference 5. The last column indicates the number of samples used to establish the average, maximum, and minimum values. The recommended daily allowance[6] is given below each vitamin.

The ascorbic acid assays included the determination of total ascorbic as well as the reduced form. Suitable figures indicating the range of total ascorbic acid content usually encountered in commercially canned foods are not available, and for this reason only the reduced form is given in Table 4.14. The values obtained for reduced, dehydro, and total ascorbic acid are given in Table 4.15; the percentage of the total ascorbic acid retained after exposure to the nuclear explosion is given in the last column.

Exposure to the nuclear explosion under the most adverse conditions resulted in only minor reductions in vitamin content. Retentions less than 80 per cent were observed in only three instances, i.e., thiamine in tuna (33 per cent), total ascorbic acid in evaporated milk (68 per cent), and riboflavin in apricots (77 per cent), and in each of these products the vitamin in question was present originally only in small amounts. *In all products tested the vitamin content after exposure to the nuclear explosion was still well within the range normally encountered in commercially produced foods.*

Total ascorbic acid retentions ranged from 68 per cent in evaporated milk to 111 per cent in luncheon meat. In evaporated milk the loss was due largely to a destruction of the dehydro form of the vitamin. In those products usually considered as significant sources of this vitamin, i.e., orange juice, peas, spinach, and tomato juice, retentions ranged from 93 to 98 per cent. When vitamin C is destroyed by oxidation, the first step in the degradation is the forma-

Table 4.14—RESULTS OF VITAMIN ASSAYS ON EXPOSED AND CONTROL CANNED FOODS

Product	Exposed	Control	Per cent retained	Normal content of commercial samples			
				Average	Max.	Min.	No. of samples

Reduced Ascorbic Acid, Mg/100 G
Recommended Daily Allowance: 75 Mg (25-year-old Man)

Product	Exposed	Control	Per cent retained	Average	Max.	Min.	No. of samples
Apricots	3.48	4.04	86	3.9	5.7	1.1	26
Evaporated milk	2.05	2.47	83				
Luncheon meat	3.48	3.87	87				
Orange juice	41.88	42.92	98	35.0	52.4	11.1	36
Peaches	3.20	3.83	84	3.8	5.8	2.0	26
Peas	9.55	10.24	93	9.3	14.1	3.1	209
Spinach	14.53	14.92	97	13.1	35.1	3.4	56
Tomato juice	16.76	16.91	99	14.4	30.0	2.5	140
Tuna	3.87	3.87	100				

Niacin, Mg/100 G
Recommended Daily Allowance: 16 Mg (25-year-old Man)

Product	Exposed	Control	Per cent retained	Average	Max.	Min.	No. of samples
Apricots	0.52	0.55	95	0.35	0.48	0.18	26
Evaporated milk	0.25	0.225	111				
Luncheon meat	3.0	3.3	91	3.0	3.5	2.2	7
Orange juice	0.28	0.29	97	0.24	0.30	0.17	36
Peaches	0.82	0.82	100	0.60	1.18	0.22	26
Peas	0.88	0.88	100	0.99	2.69	0.42	209
Spinach	0.25	0.28	89	0.32	0.64	0.15	56
Tomato juice	1.0	1.0	100	0.78	1.77	0.42	140
Tuna	10.4	10.2	102	12.40*	15.50*	7.60*	18

Riboflavin, Mg/100 G
Recommended Daily Allowance: 1.6 Mg (25-year-old Man)

Product	Exposed	Control	Per cent retained	Average	Max.	Min.	No. of samples
Apricots	0.013	0.017	77	0.022	0.039	0.010	26
Evaporated milk	0.360	0.390	92				
Luncheon meat	0.160	0.160	100	0.16	0.22	0.15	7
Orange juice	0.008	0.009	89	0.020	0.038	0.012	36
Peaches	0.015	0.018	83	0.021	0.030	0.013	26
Peas	0.060	0.060	100	0.056	0.100	0.025	209
Spinach	0.090	0.090	100	0.098	0.150	0.024	56
Tomato juice	0.009	0.009	100	0.027	0.046	0.009	140
Tuna	0.050	0.055	91	0.120*	0.170*	0.090*	18

Thiamine, Mg/100 G
Recommended Daily Allowance: 1.6 Mg (25-year-old Man)

Product	Exposed	Control	Per cent retained	Average	Max.	Min.	No. of samples
Evaporated milk	0.05	0.06	83				
Luncheon meat	0.13	0.14	93	0.3	0.39	0.22	7
Orange juice	0.05	0.05	100	0.073	0.103	0.033	36
Peas	0.11	0.12	92	0.109	0.188	0.042	209
Tomato juice	0.04	0.05	80	0.053	0.094	0.014	140
Tuna	0.01	0.03	33	0.048*	0.082*	0.016*	18

Table 4.14— (Continued)

Product	Exposed	Control	Per cent retained	Normal content of commercial samples			
				Average	Max.	Min.	No. of samples

Carotene, Mg/100 G

Recommended Daily Allowance: 5000 International Units of Vitamin A (25-year-old Man)
(If the sole source were β-carotene, this would be met by 3.6 mg.)

Product	Exposed	Control	Per cent retained	Average	Max.	Min.	No. of samples
Peas	0.38	0.30	126	0.27	0.51	0.15	209
Spinach	2.5	2.5	100	3.29	4.81	1.68	56
Apricots	0.88	0.88	100	1.29	1.74	0.93	26
Orange juice	0.01	0.01	100	0.10	0.22	0.01	36

* Oil removed.

Table 4.15 — REDUCED, DEHYDRO, AND TOTAL ASCORBIC ACID (IN MILLIGRAMS
PER 100 GRAMS) IN EXPOSED AND CONTROL CANNED FOODS

Product	Exposed			Control			Total ascorbic retained, per cent
	Reduced	Dehydro	Total	Reduced	Dehydro	Total	
Apricots	3.48	2.60	6.08	4.04	2.30	6.34	96
Evaporated milk	2.05	1.80	3.85	2.47	3.19	5.66	68
Luncheon meat	3.48	1.30	4.78	3.87	0.44	4.31	111
Orange juice	41.88	0.40	42.28	42.92	0.40	43.32	98
Peaches	3.20	1.47	4.67	3.83	1.23	5.06	92
Peas	9.55	4.41	13.96	10.24	4.54	14.78	95
Spinach	14.53	3.60	18.13	14.92	4.60	19.52	93
Tomato juice	16.76	0.14	16.90	16.91	0.96	17.87	95
Tuna	3.87	0.68	4.55	3.87	0.68	4.55	100

tion of dehydroascorbic acid. Observation of values listed in Table 4.15 indicates that there is no consistent relation between these two forms in the exposed and control foods which would indicate an increase in the dehydro form. This supports the conclusion that exposure to nuclear radiation has had little or no effect in causing oxidation of vitamin C in these foods.

Niacin was retained to the extent of 89 to 111 per cent and in most products was unaffected by exposure to the nuclear explosion. Tuna, the most significant source among the products tested, suffered no loss of this vitamin.

Riboflavin retentions ranged from 77 to 100 per cent. In apricots, the product having the lowest retention, the 23 per cent reduction represents a loss of 0.004 mg/100 g. The most important sources tested, evaporated milk and luncheon meat, retained 92 and 100 per cent, respectively.

Thiamine retentions ranged from 33 to 100 per cent, and again the greatest loss percentagewise occurred in a product having little of the vitamin present initially, namely, tuna. The most significant sources among the products tested were luncheon meat, which retained 93 per cent, and peas, which retained 92 per cent.

Carotene was unaffected in the vegetables and fruits tested.

From the results of these tests it is evident that canned foods exposed to nuclear explosions under conditions affording a high radiation flux (see introductory remarks for this chapter) are not unsuitable because of destruction of the essential nutrients studied. Such losses as do occur are small, and those products which are considered good sources of the various vitamins remain so after exposure.

4.5   TEST 5: SPECIAL FEEDING TESTS TO DEMONSTRATE SAFETY

The purpose of these tests was to determine whether there had been any toxic effects upon hermetically sealed, heat-sterilized foods exposed to maximum radiation effects of a nuclear device which might be demonstrated by short- to long-term feeding tests with animals. Results could supplement those determined by radiological scaling of the food materials (see Sec. 4.1.2b) and might reveal changes in the foods of pharmacological significance.

The foods and container sizes exposed are shown in Table 2.2, and packing details for the special pack of mixed vegetables (for monkey feeding) are given in Sec. 2.1. Exposure conditions at 1270 ft from Ground Zero, which resulted in maximum radiation dose (see introductory remarks for this chapter) are described in Sec. 2.3.

In collaboration with scientists of the industry, the Division of Pharmacology, Food and Drug Administration, designed the tests and conducted the feeding of monkeys, rats, and dogs. Upon completion of the dog feeding test, the FDA expects to publish the detailed results of the three experiments. In view of this, the results presently available are presented in summary form.

4.5.1   Monkey Feeding Test

A mixture of potatoes, sweet potatoes, carrots, and turnips, canned without added liquid in tin and glass containers (see Sec. 2.1), and evaporated milk were used to supplement the diet of monkeys over a period of 90 days. The daily supplements of one can of vegetables and one-half can of evaporated milk diluted with an equal volume of water constituted about two-thirds of the total diet of the animals, the remaining one-third being a standard laboratory chow.

Proximate analyses of the exposed and unexposed mixed vegetables showed only a normal variation. Vitamin C analyses on three exposed and three control samples gave an average of 10.0 mg/100 g and 11.1 mg/100 g, respectively. These results support the conclusion (see Sec. 4.4) that the radiation exposure had little or no effect on vitamin C.

Data on the monkeys used are given in Table 4.16.

Table 4.16— ANIMAL SCHEDULE

Monkey No.	Sex	Age, years	Duration of experiment, days	Body weight, kg Initial	Final
Supplements Exposed to Nuclear Explosion					
1	Male	$4\frac{1}{2}$	90	6.65	7.4
4	Male	3	90	3.7	4.3
5	Female	2	90	2.4	2.9
6	Female	3	90	4.3	4.3
Supplements Not Exposed to Nuclear Explosion					
2	Male	4	99	7.0	6.6
3	Female	13	90	6.0	6.0
7	Male	$2\frac{1}{2}$	90	2.85	2.75
8	Female	17	90	12.2	11.0

During the feeding experiment the animals were weighed at weekly intervals. These data were plotted, and they showed that all the animals maintained their weights. Weight fluctuations that did occur were considered normal, and they tend to discount any significance that might be attached to the differences between the initial and the final weights given in Table 4.16.

Very complete hematological studies were made on the monkeys initially at weekly and later at biweekly and triweekly intervals. The tests were as follows: hemoglobin; white blood cells; red blood cells; packed volume; sedimentation rate; and differential counts on segmented, banded, eosinophiles, lymphocytes, and monocytes. Plots indicated no significant trends that could in any way be associated with the treatment of the dietary supplements.

Radiological measurements showed that, when the first feeding began 68 days after the exposure, induced activity had declined to a value of about 45 c/m/g on the mixed vegetables and 150 c/m/g on the evaporated milk. Both of these were considered so close to background as to be of no further significance.

Each monkey was sacrificed at the end of its feeding schedule, and a microscopic pathological examination was made on the following tissues: liver, kidney, heart, lung, gall bladder, spleen, thyroid, parathyroid, salivary glands, pyloric and fundic portions of the stomach, gut, adrenal, urinary bladder, ovary and uterus or testicle and prostate, lymph nodes, skeletal muscle, and ribs. Microscopically all tissues were normal, no significant changes being observed which could be associated with the exposed diet.

Conclusion. With respect to the tests reported, no significant abnormality was noted in any of the monkeys which could be attributed to their consumption of the supplementary diets that were exposed to the nuclear explosion.

4.5.2 Rat Feeding Test

Exposed and unexposed commercially prepared strained liver and vegetable soup packed in 5-oz jars was fed to rats from a weaning age of 23 days to 20 weeks. During this period of maximum growth stress the animals ate only the strained baby food ad libitum. Since this diet is not completely adequate, a parallel group of animals was maintained on a standard rat chow known to be nutritionally adequate. The groups for feeding were as follows:

Baby food		Unexposed
Exposed	Unexposed	rat chow
15 males	15 males	15 males
15 females	15 females	15 females

The 60 rats on the baby-food diet originated from 9 litters, divided to give approximately equal representation in the exposed and the unexposed groups. At the beginning of the experiment one jar per cage of three rats was consumed daily. This rate increased gradually until four jars per cage of three males and three jars per cage of three females were consumed at the end of the experiment. All animals were observed daily, and body weights were recorded weekly.

When the rats had been on the diet for approximately 11 weeks, blood samples were taken from five males and five females of each group for hematological examination. Thereafter the same animals were sacrificed, and tissues were taken for pathological examination. The remainder were fed for about 10 more weeks, during which time an interim blood examination was made. A final blood examination was made prior to sacrificing all remaining animals, and the tissues were taken for pathological examination.

(a) Results. Proximate analyses on the baby food showed no significant differences between exposed and control samples. No destruction of vitamin B_1 was indicated, analysis giving 0.34 μg/g on the control and 0.31 μg/g on the exposed samples.

Both the exposed jars and their contents showed induced radioactivity. Radiological analysis showed that the isotopes chiefly responsible were Na^{24}, K^{42}, S^{35}, and P^{32}. During the 44 days that elapsed between exposure and the beginning of the feeding experiment, the radioactivity due to the sodium and potassium species was reduced to negligible proportions. On the day the feeding experiment started, radioactivity of the baby food with reference to phosphorus amounted to 9.94×10^{-4} μc/g. After 10 weeks of feeding the baby food was 7.7×10^{-6} μc/g

(about six times background). Bones of rats sacrificed at this time showed a slight activity, as is shown in Table 4.17.

Table 4.17 — RADIOACTIVITY OF RAT FEMURS
AFTER 10 WEEKS ON DIET (IN MICROCURIES
PER GRAM OF BONE)

Rats fed exposed baby food	Rats fed unexposed baby food
1.10×10^{-4}	1.08×10^{-6}
1.46×10^{-4}	9.77×10^{-6}
1.30×10^{-4}	0.0

Hematological analyses after 10 weeks of feeding showed no significant differences between exposed and control diets for segmented, banded, eosinophile, and lymphocyte form elements or with respect to hemoglobin or red cells. On the other hand, there was a significantly higher white cell count in the "exposed" groups (14,600 per cubic millimeter as compared to 11,430 in the "unexposed" group, significant at the 5 per cent level). This difference was also supported by counts on the group fed the nutritionally adequate standard diet. Tentatively this might be interpreted as the result of a slight stimulation of the reticulo-endothelial system due to storage of residual amounts of P^{32} in the bone. The increase in white-blood-cell count was not noted one month later or upon termination of the experiment.

Figures 4.26 and 4.27 show no significant differences in body weights between rats fed on exposed baby food and those fed on unexposed baby food. The inadequacy of the plain baby-food diet is demonstrated by weight gain of the group fed on Purina rat chow. Organ weights determined at autopsy on liver, kidneys, spleen, testes or ovaries, adrenals, and thyroid showed no significant differences between the exposed and unexposed baby-food groups.

Pathological examination was made on 12 animals from both the exposed and the control baby-food groups. Tissues examined were the heart, liver, lung, kidney, urinary bladder, testicle and prostate or ovary and uterus, spleen, thyroid, esophagus, stomach, intestine, colon, pancreas, adrenal, and bone. Histological studies were made on three males and three females from the groups that were sacrificed at 10 weeks and on the remainder at 20 weeks when the experiment terminated. In general, the tissue examinations revealed no significant differences between the exposed and the unexposed groups either at 10 or at 20 weeks.

(b) Conclusion. No evidence was developed to show that exposure of baby food to a nuclear explosion produced harmful effects in rats that ate such a treated preparation. There is a tentative indication that the small residual amount of induced radioactivity produced some stimulation for a temporary increase in the white-cell count.

4.5.3 Dog Feeding Test

Four male beagles were fed control canned beef stew for 29 weeks, and four male litter mates received bomb-exposed stew for a similar period. Two hematological examinations were performed on each dog prior to the start of the experiment and thereafter at 2, 4, 12, and 24 weeks. Originally the dogs were fed 2 lb of stew per day. However, two pairs were increased to 3 lb/day in accordance with their weight and appetite. At the time this report was written, no additional dietary supplement had been employed. All dogs appear normal in activity, growth, appetite, and hematology. The only abnormality observed has been an uncontrolled dermatitis in one control dog. The dietary regimen was started on July 18, 1955, and was planned to continue for one year.
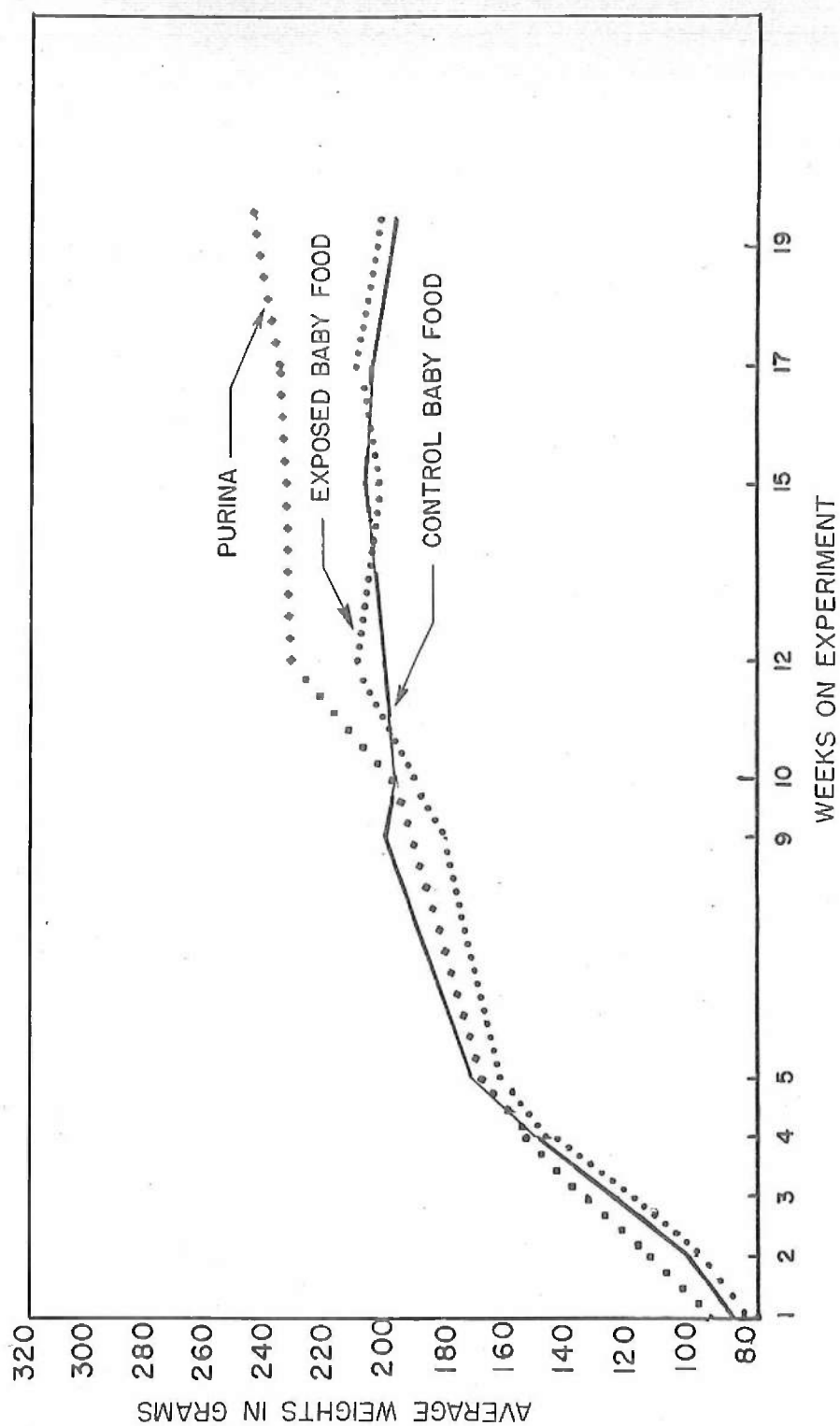
Fig. 4.26 — Body-weight curves for female rats.

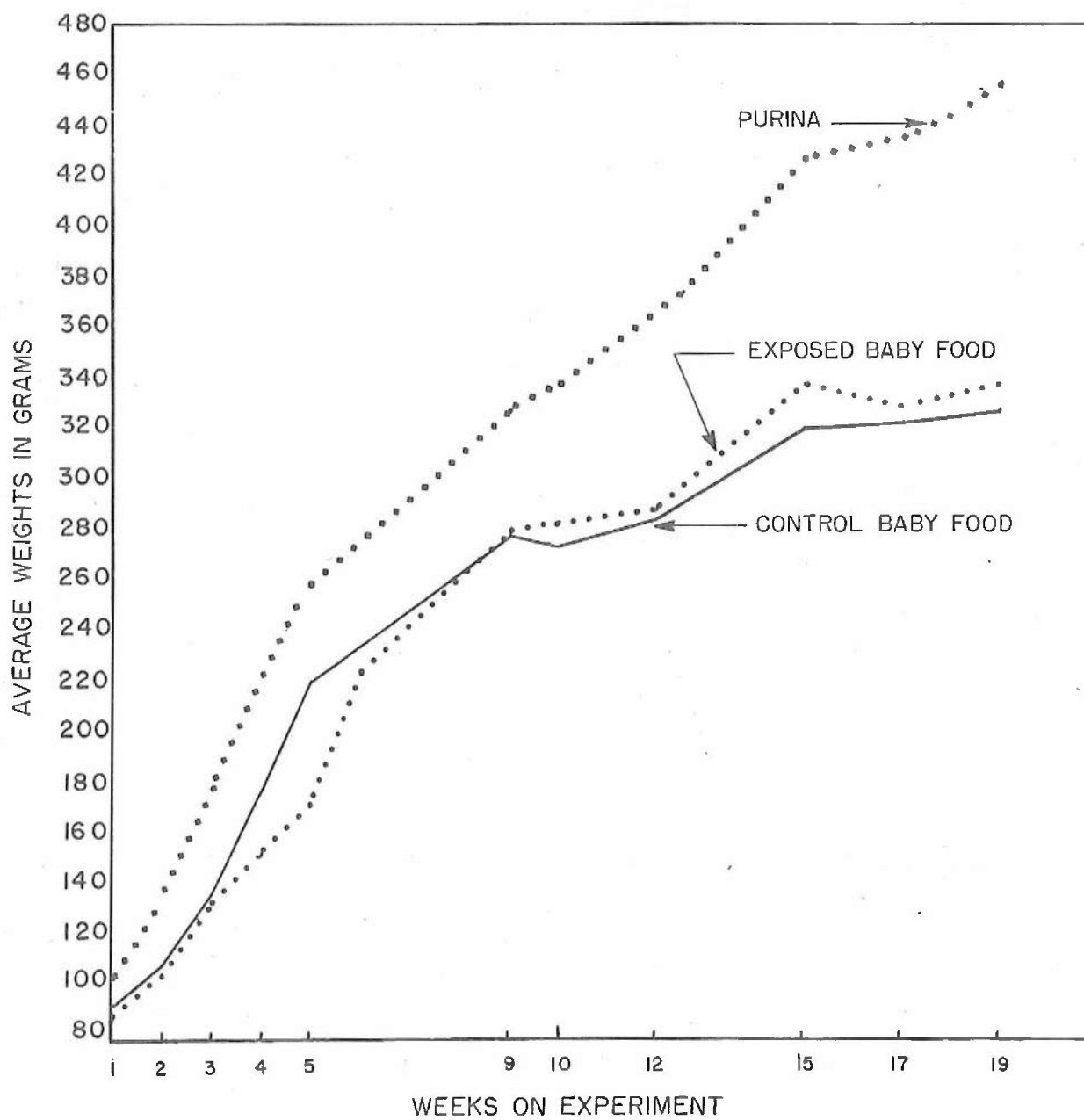| First 10 weeks	Last 9 weeks
12 rats on Purina	7 rats on Purina
15 rats on exposed baby food	10 rats on exposed baby food
15 rats on control baby food	10 rats on control baby food

Fig. 4.27 — Body-weight curves for male rats.

First 10 weeks
   12 rats on Purina
   15 rats on exposed baby food
   15 rats on control baby food

Last 9 weeks
   7 rats on Purina
   10 rats on exposed baby food
   10 rats on control baby food

REFERENCES

1. Los Alamos Scientific Laboratory, "The Effects of Atomic Weapons," U. S. Government Printing Office, Washington, D. C., 1950.
2. U. S. National Committee on Radiation Protection, "Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water," National Bureau of Standards Handbook 52, p. 15, National Bureau of Standards, Washington, D. C., 1953.
3. S. Kinsman, "Radiological Health Handbook," p. 135, U. S. Department of Health, Education, and Welfare, Washington, D. C., 1954.
4. E. B. Roessler, J. Warren, and J. R. Gymon, Significance in Triangular Taste Tests, Food Research, 13: 503-505 (1948).
5. E. J. Cameron and J. R. Esty, "Canned Foods in Human Nutrition," National Canners Association, Washington, D. C., 1950.
6. "Recommended Dietary Allowances," Publication 302, National Academy of Sciences, National Research Council, Washington, D. C., 1953.

CHAPTER 5

SUMMARY

This summary chapter applies to canned foods in tin and glass containers exposed to the effects of a nuclear explosion. Exposures covered a wide range of civilian handling conditions in homes, commercial storage, retail outlets, and emergency shelters to determine the suitability for use of canned foods either immediately or after some period of storage. Examinations of samples at 4700 ft or further from Ground Zero were made 6 hr after the open shot. At closer distances recoveries were made on the third and fourth days.

1. *Canned foods in unbroken tin or glass containers subjected to an atomic blast are suitable for immediate use when located in shelters or other structures effective in protecting personnel against lethal radiation or blast effects.* Their induced radioactivity is not at a dangerous level, and any container failure is readily discernible. *Canned foods that might be recoverable from critically exposed areas within the zone of complete destruction could be pressed into emergency service after three or four days.*

2. At distances beginning at 2250 ft from Ground Zero in the area showing major damage to the structures housing the canned-foods exposures (up to slightly over a mile in this test), some obvious container failures occurred as a result of mechanical breakage or perforation by flying missiles. This is a type of failure that could occur in many types of natural disasters. Even in the case of an aboveground shelter so badly shattered that no personnel could have survived crushing or the lethal doses of radiation, 67 per cent of the canned foods were recovered in usable condition. *To minimize mechanical crushing and perforation damage, basement storage of canned foods is preferable to kitchen storage, and the storage area should be out of direct line with windows or doors.* In six structures (at 4700, 5500, 6800, 7800, 10,500, and 15,000 ft from Ground Zero), no products suffered effects from radiation.

3. Under extreme conditions of exposure to blast overpressures of 45 psi at $\frac{1}{4}$ mile from Ground Zero (comparable to complete destruction of structures), there was some obvious container destruction, and radioactivity was induced in the foods and containers by the high radiation level. It can be assumed that the use of such foods would be limited to short periods and that they would not be accessible until three or four days after the explosion. *Food recovered after three or four days from such an area of complete destruction may be used and will have normal flavor and texture, as has been attested by panels of tasters.*

If the unopened container shows considerable activity when monitored after an explosion, it should not be discarded. Container radioactivity has no bearing on the suitability of the food for use. The container should be brushed, wiped, or washed to remove fall-out material and opened so that the contents can be monitored. *Very active containers, in many instances, will contain food that is entirely safe.* Visual indications of extreme exposure are sharp crushing deformations of can bodies or coloration of glass jars.

4. Exposure of canned foods to intense radiation at $\frac{1}{4}$ mile from Ground Zero resulted in no significant losses in nutrient values. In all products tested the ascorbic acid, niacin, ribo-

flavin, thiamine, and carotene content, after exposure to the nuclear explosion, was still within the range ordinarily found in commercial production. *Such nutritive losses as do occur are small, and those products that are considered good sources for the various vitamins remain so after exposure.*

5. Monkeys fed for three months on a diet consisting substantially of critically exposed food showed no adverse effects. Rats fed completely on a diet of canned baby food exposed in the same fashion at $\frac{1}{4}$ mile from Ground Zero showed the same growth characteristics as those fed on unexposed baby food, and no harmful effects were detectable.